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(54) **HOLLOW FIBRE FILTER CARTRIDGE AND HEADER.**

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EP 0 282 539 B1

Description

This invention relates to hollow fibre filters and more particularly to shells or casings which house the fibres and to the headers through which fluids pass to and from the shell.

In this specification, the term "hollow fibre" refers to fibres of a tubular shape having a continuous passageway (or lumen) disposed substantially along the axial centre line of the fibre. The term "membrane" refers to porous or microporous material which may, inter alia, be in the shape of a hollow fibre.

Hollow fibre filters consist of a bundle of hollow, porous, polymeric fibres which can be arranged in the shell or casing in either a tube-in-shell or candle-in-shell configuration.

Tube-in-shell filters which are widely used for ultra-filtration and microfiltration consist of a number of hollow porous fibres aligned side by side as a bundle and which are secured at each end by being cast in a resin, care being taken to keep the lumens of the fibres open. The bundle thus formed is either permanently bonded at each end to an outer shell, which may be made of plastic material, or it is fitted or moulded with sealing means for insertion into a reuseable, usually metal, shell.

Candle-in-shell filters are similar except that the fibre bundle is attached to the cartridge shell at one end, and at the other the ends of the fibres are each sealed but left free of one another. Alternatively, the fibres in the bundle are each looped so that both ends of each fibre are sealed in the resin casting.

The assembly of the fibre bundle and shell forms what is called a filter cartridge. At each end of the cartridge there is a header through which fluids pass to and from the cartridge. The feed to be filtered may be applied to either the inside or the outside of the fibres with the filtrate being withdrawn from the other side of the fibres.

Cartridges and headers are often bonded or welded to one another to form an integral structure. Sometimes the whole fibre plus shell plus header assembly is called a cartridge, but in this specification the term "cartridge" applies to the assembly of fibre bundle and shell without the headers and the term "filter" applies to the cartridge plus headers.

A plurality such filters may be connected in parallel or in series and are usually coupled by threaded screw fittings to piping from a feed pump and to piping leading to a filtrate collection apparatus. The term "bank", "bank of filters", or "filter bank" is applied to such an assembly of filters. The piping assemblies which deliver feedstock to and collect filtrate and concentrate from a plurality of filters, are each called a manifold.

Existing designs have many disadvantages. For example, screw fittings are expensive and take up space. Furthermore, in many applications (such as shipboard or portable use) the maximum possible area of filter membrane must be contained in the smallest possible volume. Filters with protruding fittings do not use space economically. In addition, portable applications require light weight construction using a minimum of materials.

Another disadvantage of existing designs is that equipment incorporating lightweight cartridges and headers made of polymeric plastic materials is not transportable in an assembled or partially assembled form. Because piping and screw fittings support a cantilevered assembly, they can snap if transported on a truck in rough terrain or if delivered by helicopter or parachute.

There is a need for compact transportable equipment for mobile or military use. There is also a need that such equipment be at least partially assembled during transport and that it be easy to complete the assembly for rapid use in the field.

A disadvantage of metal shells and headers is that they are expensive, and, for economy, require that the bundle of hollow fibre membranes be replaceable within the metal shell. This is achieved with a series of O-rings at each end of the bundle which must then be inserted with considerable mechanical force into the metal tube and the metal tube reassembled into or onto the header. Fibre bundle inspection and replacement is, as a consequence, difficult.

Furthermore, it is desirable to have a range of filter dimensions made available for different applications. Varying feedstocks to be filtered contain different amounts of impurities and for economy, those with few impurities should be filtered at high flux rates. Long cartridges containing fine fibres are not able to provide a high velocity of drawoff of filtrate because of the hydraulic pressure drop of high volumetric flow rates in the narrow lumens of the fibres and hence short cartridges are required. Conversely, dirty feeds require longer cartridges where the lower flux rates present no problems of lumen pressure drop. With metal shells and headers, variable cartridge and filter dimensions are expensive to implement and service.

Another problem with prior art designs arises because different types and batches of fibres have different quality in terms of initial defects or service failure rates per unit of fibre surface area. If cartridges can be manufactured cheaply enough then economy, convenience and utility can be optimised by varying the number of fibres per cartridge.

Thus, higher defect-rate fibres could be manufactured into a cartridge with fewer fibres so that the chance, and hence the penalties, of a failed cartridge would be less. Because of the limitations imposed by practically obtainable minimum defect rates, optimal cartridge diameters for industrial porous hollow fibre microfilters are

usually 70 to 80 mm containing 1 to 2 square metres of membrane. These figures will, of course, increase as fibres become more reliable and cheaper, and be constrained only by practical limitations of feedstock penetration to all parts of the hollow fibre membrane bundle during operation.

As soon as one fibre breaks or develops a fault, integral plastic cartridges and headers must be replaced. Moreover, repair of damaged fibres is not economic.

Cartridges are tested for failure by means of a bubble pressure test. When water occupies all of the pores in the membrane, a certain pressure, known as the bubble point of the membrane, has to be exceeded to overcome the interfacial tension of the water in the pores. In the bubble pressure test, air is forced back into the lumens of the wetted fibre. Failed fibres allow air to pass through the fibre walls at a pressure lower than the bubble point of the membrane. The opacity of prior art industrial cartridges and headers does not allow visual detection of a failed cartridge, and each cartridge must be individually tested after first being disassembled from the filter bank. Individual small medical cartridges have usually been made transparent, at greater cost, to allow bubble testing.

Hitherto, feed has usually been pumped into the shell as a radial jet at right angles to the direction of flow within the shell. With radial introduction of feed, the fibres at the inlet end on the opposite side from the inlet receive little feed. This is because the feed stream impacts against the fibres and is diverted down them, rather than swirling round them. Similarly, in the absence of evenly distributed withdrawal of feed, dirt accumulates at the outlet end against the side of the fibre bundle remote from the outlet. A considerable amount of useful filter surface is by-passed, which is inefficient.

United States Patent specifications 4,565,630, 4,578,190, 4,639,353, 4,617,161, 4,568,456, 4,632,756, 4,414,113, 4,390,575, European Patent specifications 186,293, 163,900, Japanese Patent specifications 61-031,164, 60-261,507, 60-261,506, 60-061,006, 59-115,702, 58-041,830, 58-143,805, 57-159-502, 57-150,402 and United Kingdom Patent specification 2,090,546 all disclose slight variations on the general principle of filter design in which a plurality of mostly hollow fibre membranes are disposed inside a shell with the ends of the fibre lumens sealed from the outside of the membranes. The shell has a feed inlet as well as a filtrate outlet and usually has a feed outlet or return, all of which are in the form of a spigot or port. None of these previous designs provides an efficient means of connecting a plurality of filters.

United States Patents 4,346,006, 4,400,276, 4,497,104, 4,308,654, Japanese Patents 65-024,004, 61-157,308, 61-057,206, 59-115,702, 59-130,503, 51-093,788, 51-103,083, 56-141,801, 56-037,002, 55-157,304, 58-109,104, European Patent 183,256 and Russian Patent 1,158,211 all disclose slight variations on methods of manufacturing hollow fibre membrane cartridges and filters which have the general form of parallel or substantially parallel hollow fibre membranes sealingly enclosed in a shell to form a cartridge, with a header or shell entry and exit ports for feedstock, filtrate and concentrate, however, none of these inventions makes use of the headers as an efficient means of connecting more than one filter in a bank.

A review of header and cartridge or filter designs is given in French Patent 2,267,138 which discloses a hollow fibre membrane filter in which the bundle of fibres is enclosed by an elastic, tightly wrapped sheath. There is a common factor in the design of most prior art hollow fibre membrane filters, being that of disposing a bundle of mostly parallel hollow fibre membranes inside a usually cylindrical shell. Sometimes the shell has inlet ports for feedstock or filtrate, however, a header will always provide a sealing means so that the ends of the lumens are separate from the outside of the fibres. The prior art does not, however, disclose an efficient means of connecting a plurality of cartridges.

DISCLOSURE OF THE INVENTION

It is an object of this invention to provide a header for a hollow fibre filter which provides an efficient means of connecting more than one filter in a bank.

According to one aspect of the invention there is provided a filter comprising:-

(i) an elongated open-ended casing having transfer ports adjacent each end thereof to provide fluid communication between the outside and inside of the casing,

(ii) a bundle of hollow, porous, polymeric fibres within the casing,

(iii)a first plug at one end of the casing in which one end of the bundle of fibres is embedded whereby the plug prevents flow of fluid out said one end of the casing other than through the lumens of the fibres,

(iv) a second plug closing the other end of the casing,

(v) a first transfer header at said one end of the casing and including:

a) a body portion that encloses said one end of the casing,

b) a feed passageway extending through said first header having an inlet at one end for receiving feed to be treated, an outlet at the other end adapted to be connected to the inlet of the feed passageway of an adjacent first header and a discharge port for delivering feed to the casing,

c) an inlet chamber in fluid communication with the discharge port of the feed passageway and the transfer port at said one end of the casing,

d) an outlet chamber for receiving filtrate from the open ends of the fibre lumens, and,

e) a filtrate passageway extending through said first header having a receiving port for receiving filtrate from the outlet chamber, an outlet at one end for discharging filtrate and a inlet at the other end adapted to be connected to the outlet of the filtrate passageway of an adjacent first header,

(vi) a second transfer header at the other end of the casing and including:

a) a body portion that encloses said other end of the casing,

b) an outlet chamber for receiving treated feed from the transfer port at said other end of the casing, and,

c) a treated feed passageway extending through said second header having a receiving port for receiving treated feed from the outlet chamber, an outlet at one end for discharging treated feed and an inlet at the other end adapted to be connected to the outlet of the feed passageway of an adjacent second header.

In a modification of the invention, the second plug closing the other end of the casing has embedded therein the other end of the bundle of fibres whereby the second plug prevents flow of fluid out said other end of the casing other than through the lumens of the fibres and the second header has an outlet chamber for receiving filtrate from the fibre lumens and a filtrate passageway extending therethrough which has a receiving port for receiving filtrate from the outlet chamber, an outlet at one end for discharging filtrate and a inlet at the other end adapted to be connected to the outlet of the filtrate passageway of an adjacent first header.

Preferably, a bank of such filters is connected together by their headers so that the feed passageways and filtrate passageways are connected in series whereby each filter may be supplied from the one source of feed with a portion of the feed being introduced into the inlet chamber of each filter, the filtrate from each filter is directed to the interconnected filtrate passageways and the treated feed from each filter is directed to the interconnected treated feed passageways.

In order that the invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings in which:-

Fig. 1 is a diagrammatic view of a tube in plastic shell hollow fibre filter device typical of the industrial prior art,

Fig. 2 is a partly broken-away view of one end of the prior art filter device shown in Fig. 1,

Fig. 3 is a view similar to Fig. 2 of a modified form of the filter,

Fig. 4 is a view similar to Fig. 2 of a further modified form of the filter,

Fig. 5 is a perspective view of a single filter unit according to one embodiment of the invention,

Fig. 6 is an exploded, partly cut away view of one end of the filter unit shown in Fig. 5,

Fig. 7 is a view taken along lines A-A of Fig. 6,

Fig. 8 is a front elevational view of an assembly of the filter units shown in Figs. 2 and 3,

Fig. 9 is a partly broken-away view of the top end of the filter unit shown in Figs. 5 to 7,

Fig. 10 is a view similar to Fig. 9 of a modified form of the top end,

Fig. 11 is a view similar to Fig. 9 of a further modified form of the top end,

Fig. 12 is a view similar to Fig. 9 of yet a further modified form of the cartridge end,

Fig. 13 is a partially broken-away side elevational view of a candle-in-shell cartridge and header according to another embodiment of the invention,

Fig. 14 is a graph comparing differential pressure against flow rate at 20°C for a filter having the outlet end shown in Fig. 12 with the outlet end shown in Fig. 9,

Fig. 15 is a graph comparing differential pressure against flow rate for a filter having the outlet end shown in Fig. 12 at 70°C with a filter having the same end at 20°C,

Fig. 16 is a graph comparing differential pressure against flow rate at 20°C for a filter having the outlet end shown in Fig. 11 with a filter having the outlet end shown in Fig. 9,

Fig. 17 is a graph comparing differential pressure against flow rate for a filter having the outlet end shown in Fig. 11 at 70°C, with a filter having the same end at 20°C and,

Fig. 18 is a graph comparing differential pressure against flow rate at 20°C for a filter having the outlet end shown in Fig. 10 with a filter having the outlet end shown in Fig. 9.

The prior art tube-in-shell hollow fibre filter shown in Fig. 1 includes a plastic casing 20 that houses a bundle of hollow, porous, polymeric fibres 21. The respective ends of the hollow fibres 21 are embedded in a resin plugs 22 in each header 25. Feed is introduced through inlet 23 in the direction of arrow A and treated feed is discharged through outlet 24 in the direction of arrow B. Filtrate is drawn off through outlets 26 in the directions of arrows C and D.

One end of the filter of Fig. 1 is shown on an enlarged scale in Fig. 2. The header 25 is made of two parts

27, 28 within which is located a collar 29 that supports a spigot 30 leading from the inlet 23. In this embodiment of the prior art filter, the inner end 31 of the spigot 30 is flush with the inner surface of the collar 29 and the casing 20 projects into the header part 28 with its end 32 terminating beyond the spigot 30.

The modified version of the end of the prior art filter shown in Fig. 3 is substantially similar to that shown in Fig. 2 except that the spigot 30 projects beyond the inner surface of the collar 29 and that the inner end 31 of the spigot 30 has a cut-away portion 33.

The modified version of the end of the prior art filter shown in Fig.4 is substantially similar to that shown in Fig. 3 except that the inner end 32 of the casing 20 projects into the header part 28 but terminates short of the spigot 30.

The specific designs of the prior art filters shown in Figs. 2 to 4 will be referred to below in relation to Example 3 which demonstrate the effectiveness of filters according to the invention.

One embodiment of a filter unit according to the invention is shown in Figs. 5 to 7. The filter unit includes a casing 40, a first transfer header 41 at the top of the casing 40 and a second transfer header 42 at the bottom of the casing 40. The casing 40 contains a bundle of hollow, porous, polymeric fibres 43 (see Figs. 6 and 7). In this instance, each fibre, which is made of polypropylene, has an average pore size of 0.2 µm, a wall thickness of 200 µm and a lumen diameter of 200 µm. There are 3,000 hollow fibres in the bundle 43 but this number, as well as the individual fibre dimensions, may be varied according to operational requirements.

The top of the casing 40 is shown in Figs. 6 and 7 and, in this instance, the bottom of the casing 40 is the same although this need not be so as will be evident from the embodiment of the invention described below in relation to Fig. 13.

As can be seen in Figs. 6 and 7, the casing 40 consists of a main tube 44 and an end portion 45 which includes a skirt 46, a collar 47 and an end piece 48. The main tube 44 which is bonded both to the skirt 46 and the collar 47 terminates beneath the collar 47.

The end piece 48 has a plug 49 (see Fig. 7) of polyurethane resin in which is embedded the upper ends of the fibres 43 whereby the plug 49 prevents flow of fluid out of the end of the casing 40 other than through the lumens of the fibres 43. Transfer ports 50 are formed in the end piece 48 beneath the plug 49.

As can be seen in Fig. 6, the main body 51 of the header 41 has a skirt 52 which depends downwardly from the body 51 and receives the collar 47. In this instance the collar 47 is bonded to the skirt 52, however, it may be releasably secured thereto by means of "O" rings.

The internal diameter of the main body 51 is larger than the external diameter of the end piece 48 of the casing 40 to provide an annular inlet chamber 53 (see Fig. 9) that is closed at the top by an inner shoulder 54 of the header 41 and at the bottom by the collar 47 of the casing 40.

The header 41 has a feed passageway 55 extending through an off-set portion 56 of the body 51. The feed passageway 55 has an inlet 57 at one end for receiving feed to be treated, an outlet 58 at the other end adapted to be connected to the inlet of the feed passageway of an adjacent top header and a discharge port 59 for delivering feed to the inlet chamber 53. Around the periphery of the inlet 57 there is a recess 60 which receives an "O" ring 61 and around the periphery of the outlet 58 there is a bevelled annular projection 62. As can be seen in Figs 5 and 6, the end faces of the off-set portion 56 are planar and parallel.

Transfer apertures 50 in the end piece 48 of casing 40 permit flow of feed from the inlet chamber 53 to the interior of the casing 40 where it is applied to the external surfaces of the fibres 43. Filtrate drawn off from the lumens of the fibres 43 is collected in the outlet chamber 63.

A filtrate passageway 64 that extends through the top portion 65 of the header 41 has a receiving port 66 for receiving filtrate from the outlet chamber 63, an outlet 67 at one end for discharging filtrate and an inlet 68 at the other end adapted to be connected to the outlet of the filtrate passageway of an adjacent top header. Around the periphery of the inlet 68 there is a recess 69 which receives an "O" ring 68 and around the periphery of the outlet 67 there is a bevelled annular projection 71. As can be seen in Figs. 5 and 6, the end faces of the top portion are planar and parallel.

In this embodiment of the invention, a similar header 42 provided at the bottom of the casing 40 has a treated feed passageway 72 in an off-set portion 73 of the body 51 and a filtrate passageway 74 that extends through bottom portion 75 of the header 42. In all other respects, the bottom header 42 is the same as the top header 41.

Filter units as described in relation to Figs. 5 to 7 may be assembled together to form a bank of filter units as shown in Fig. 8 without the need for pipe work or additional manifolds between each filter unit. To achieve this, the planar end faces of the off-set portions 56 and 73 and of the top and bottom portions 65 and 75 of the headers 41 and 42 are butted against the end faces of adjacent filter units. Correct alignment of the feed passageways 55, the treated feed passageways 72 and the filtrate passageways 64 and 74 is assured by means of pins 76 in the end faces which engage in recesses 77 in the adjacent end faces.

The right hand end faces of the off-set portion 56 and the top portion 65 of the right hand header 41 of the

bank in Fig. 8 are covered by a first closure plate 78 having an inlet means 79 in communication with the inlet 57 to the feed passageway 55 of the right hand header 41. The left hand end faces of the portions 56 and 65 of the left hand header 41 are closed by a second closure plate 80 having outlet means 81 in communication with the outlet 67 of the filtrate passageway 64 of the left hand header 41.

The right hand end faces of the off-set portion 73 and bottom portion 75 of the right hand bottom header 42 are covered by a third closure plate 82 with closes both the inlet 68 to filtrate passageway 74 and the inlet 55 to the treated feed passageway 72 of the right hand header 42. A fourth closure plate 83 having outlet means 84 in communication with the treated feed passageway 72 and outlet means 85 in communication with the filtrate passage 74 of the right hand header 42. Thus, feed is introduced into the filter bank 40 in the direction of arrow A and passes through the connected passageways 55, treated feed is discharged from the connected passageways 72 in the direction of arrow B and filtrate is drawn off from the connected passageways 64 and 74 in the direction of arrows C and D.

The filter units of the bank in Fig. 8 are held together by bolts 86, 87, 88 and 89 which pass through respective passageways 90, 91, 92 and 93 (see Fig. 5) formed in the top portions 65, the off-set portions 56 and 73 and the bottom portion 75 respectively of the headers 41 and 42. The bolts 86 to 89 also retain the closure plates 78, 80, 82 and 83. When the bolts are secured in position, the respective bevelled annular projections 62, 71 engage against the "O" rings 61 and 70 to effect a seal between adjacent filter units. A single filtration unit form of the invention can be made by applying the closure plates 78, 80, 82 and 83 to the end faces of the filter unit shown in Figs. 5 to 7.

The top of the filter cartridge and header assembly shown in Figs. 5 to 7 is shown in section in Fig. 9. It will be seen that the main tube 44 of the casing 40 terminates short of the transfer ports 50. Annular grooves 94 formed in the inner face of end portion 48 between the upper and lower limits of the transfer ports 50 assist the flow of feed to the fibres 43. In this instance, there are four evenly spaced grooves 94 of identical, uniform, cross-section which intersect the transfer ports at right angles to the axis of the ports 50. The end portion 95 of the main tube 44 has a reduced external diameter to provide a base for a screen 96 which is shown in dotted outline.

The modification of the top of the filter cartridge and header shown in Fig. 10 is substantially similar to that shown in Fig. 9 except that the upper end of the main tube 44 projects past the lower groove 94 and the bottom of the transfer ports 50.

The modification of the top end shown in Fig. 11 is substantially similar to Fig. 9 and that of Fig. 12 is substantially similar to Fig. 10 except that the grooves 94 have been omitted. As can be seen in Figs. 9 to 12, the transfer ports 50 are not in alignment with the feed inlet 59 but are at right angles thereto. Although not fully apparent from the drawings, there are two ports 50 on one side of the end piece 48 and two ports 50 on the other side of the end piece 48.

The bottom header may be the same as any one of the headers shown in Figs. 9 to 12 to provide a cross-flow filter in which feed is applied to the top of the cartridge and treated feed is withdrawn from the bottom of the cartridge. Although the filter is shown in a vertical disposition with feed applied to the top of the cartridge, it will be appreciated that the feed could be applied to the other header and that the filter may be in other dispositions such as inclined or horizontal. Furthermore, the transfer ports may be of any convenient configuration and disposition.

A further modification of the invention is shown in Fig. 13 wherein a different lower header provides a candle-in-shell hollow fibre filter. The filter shown in Fig. 13 includes a casing 100 in which is located a bundle of fibres 101 the upper ends of which are embedded in resin in the upper header 102 which is similar to the upper header 42 of the embodiment shown in Figs. 5 to 8. The lower ends of the fibres 101 are each sealed but are left free of one another as can be seen in the lower portion of Fig. 13.

The lower header 103 is substantially the same as the upper header 102 and as such includes a main body portion 104 that has an upwardly extending skirt 105. A pair of "O" rings 106 form a seal between lower extremity of the casing 100 and the bottom portion of the header 103.

The internal diameter of the skirt 105 is larger than the external diameter of the enlarged end of the casing 100 to provide an annular inlet chamber 107 that is closed at the bottom by the bottom portion of the header 103 and at the top by a collar 108 bonded to the casing 100. "O" rings 109 form a seal between the upper extremity of the skirt and the casing 100.

The filter units of this invention are low cost if manufactured in plastic in that the feed and filtrate passageways or manifolds are incorporated into the header. Furthermore, cost advantages accrue as the header is cast entirely in one piece and is of a symmetrical design so that it may be used for both ends of a tube-in-shell cartridge.

A very small modification of a top header by blocking either the filtrate passageway or the treated feed passageway allows the header to be used for the opposing end of a candle-in-shell cartridge.

The low cost of the filter units allows the optimisation of economy by choice of cartridge fibre surface area versus number of defects per unit area of fibre.

As indicated above, the cartridge and header can be easily assembled with O-rings, or they may be sealed by bonding if desired. The feed passageways and filtrate passageways are not connected so that there is no chance of cross contamination in the event of a faulty "O" ring.

The rugged construction of the modules enable them to be transported in at least partially assembled form over rough terrain or delivered by helicopter into difficult sites.

As the header is compact and takes up little more cross sectional area than the fibre bundle a high density of membrane per unit volume can be achieved. There is no need for internal pipework for filtrate and feedstock ducts. The only pipework needed is at each end of long banks of assembled cartridges and headers. The units may be stacked in three dimensions to give a tightly packed array. Thus, for a given cartridge dimension and membrane surface area, the invention results in a very compact assembly.

The invention is light weight since the self-manifolding header uses less material and requires no piping with a bank of filters. Futhermore, the energy loss at elbows and branches does not occur, and the fluid dynamics is more efficient.

The invention also provides versatility of choice of cartridge. Cartridges of differing and variable dimensions can easily be interchanged between detachable headers without modification to the remainder of the filter equipment. Thus adjustment of cartridge length for different feedstock properties is possible.

Insertion of the cartridge into the detachable form of header is made easy in that the collar is bonded to the cartridge casing so that the "O" rings at the end of the cartridge casing need not be forced past the first pair of O-ring fittings of the header.

The space between the header, the cartridge and cartridge collar creates a large feed chamber, which, with the transfer ports in the end of the cartridge casing, allows feed to enter evenly onto the outside of the fibres. The feed stream enters tangentially to the feed chamber, causing swirling of the feed stream around the chamber.

For tube-in-shell filters, the chamber and transfer ports around the exit end of the cartridge allow rapid removal of dirt and solid material by the swirling, tangentially flowing feed exit steam. When backwashing, the inlet design facilitates removal of deposits that have been loosened from the outside of the fibres by the liquid or gaseous backwashing surge. For candle-in-shell filters, cleaning is automatic as the flow sweeps away dirt from the bottom of the cartridge. There is no dead space for the dirt to accumulate.

The candle-in-shell filter has a much smaller exit restriction because there is no direction change whilst the feed is flowing past any of the active filter area. The filter is placed upright with the hollow fibres dangling downwards, and the feed is allowed to flow straight past the free ends. Any operation such as backwashing or clearing lumens of liquid is done in such a way as to keep the free ends under tension by having at least some flow in the downwards direction on the outside of the fibres.

By manufacturing the header or cartridge, or both, from a clear plastic, a failed cartridge may easily be detected during bubble testing. The wetted fibres of the failed cartridge pass bubbles under a much lower air back pressure than the fibres of sound cartridges as in the bubble test described above. Visual detection of a failed cartridge may also be accomplished by incorporation of a clear inspection port in either the header or the cartridge shell. With turbid feeds which produce a clear filtrate, a failed fibre may be detected by turbidity in the permeate from the filter.

As the cartridge shell and the assembly is low cost, the amount of fibre surface area per cartridge can be optimised for different fibres. Thus fibres with a high initial or in-use defect rate per area of fibre can be manufactured into cartridges containing less fibres than would be the case for low defect rate fibres. As a consequence, the penalty of a failed cartridge is less.

The flexibility in choice of construction allows the selection of a corrosion resistant manufacturing material for both the cartridge and the header for a particular application. The materials of construction may also be chosen to resist high temperatures such as those encountered in handling hot foodstuffs.

When the equipment is assembled, the feed and filtrate streams are not connected and are separated by two O-ring seals that provide good protection against cross contamination. However, for critical uses such as very pure water, the header may be bonded to the cartridge, thus providing even greater protection against cross contamination. The low cost of the apparatus allows it to be discarded if necessary for these special uses.

As will be apparent for the foregoing description, banks of cartridges and headers may be connected in series or parallel to accommodate differing feedstocks.

The invention will now be further described by reference to the following examples:

EXAMPLE 1

A series of water flux tests were carried out on banks of five cartridges of both the prior art design and the design of the present invention.

The results are tabulated below:-

Average Transmembrane Pressure Drop (kPa)	Filtrate Rate (L/hr)	Cartridge design
65	5,300	Fig. 1
88	6,000	Fig. 1
100	7,200	Fig. 1
88	9,000	new

The results showed a 50% improvement in filtrate rate for the design of the present invention over the prior art design shown in Fig. 1.

EXAMPLE 2

A series of experiments investigating the effect of high cross-flow on pressure drop down filters with the self manifolding header of the present invention was completed and the results compared for three modifications to the basic design. All the tests were performed on a single filter with water as the feedstock. Tests were carried out for four designs at two temperatures, 20°C and 70°C.

The four filter units tested each had identical headers at each end of the cartridge. The headers used are those shown in Figs. 9 to 12 and the results graphed in Figs. 15 to 18.

The graphs in Fig. 14 shows a comparision of differential pressure aginst recirculation feed flow rate for the filter unit with an extended tube and smooth casing at both ends (Fig. 12 embodiment) and the filter unit with the shorter tube and grooves (Fig. 9 embodiment), at 20°C.

The graph of differential pressure against feed flowrate for the filter unit with an extended tube and smooth casing (Fig. 12 embodiment) is shown in Fig. 15 for feed at 20°C and 70°C.

The graph in Fig. 16 shows a comparison of differential pressure against recirculation feed flow rate for the filter unit with the shorter tube, and a smooth casing at both ends (Fig. 11 embodiment) and the filter unit with the shorter tube and grooves (Fig. 9 embodiment), at 20°C.

The graph of differential pressure against feed flowrate for the filter unit with the shorter tube and smooth casing (Fig. 11 embodiment) is shown in Fig. 17 for feed at 20°C and 70°C.

The graph in Fig. 18 shows a comparison of differential pressure against recirculation feed flow rate for the filter unit with the extended tube, and grooves at both ends (Fig. 10 embodiment) and the filter unit with the shorter tube and grooves (Fig. 9 embodiment), at 20°C.

The filter unit with the extended tube and grooves (Fig. 10 embodiment) gave the best performance. The filter with the shorter tube and grooves (Fig. 9 embodiment) gave superior performance to both the filter with the extended tub and smooth casing (Fig. 12 embodiment) and the filter with the shorter tube and smooth casing (Fig. 11 embodiment). Both filters with the smooth casing (embodiments of Figs. 11 and 12) gave similar performances.

In the two cases tested at 70°C, the improvement in pressure drop response was greater.

The filter unit with the grooves formed on the inside of the outlet end of the casing (Fig. 9) gave superior

performance to both the prior art design and the filter unit of this invention without the grooves (Fig. 11). This improvement was more apparent at the higher test temperature, as can be seen when comparing results of Fig. 18 with Fig. 14 (temperature 20°C) and Fig. 15 (temperature 70°C).

The filter units of this invention with both an extended casing on the outlet and grooves on the inside of the casing (Fig. 10) gave the best performance of all of the designs tested at both temperatures, as can be seen by the second curve on Fig. 18.

EXAMPLE 3

A series of tests using low-fouling feedstock on a range of new and old filter designs was carried out. The filters were operated in three different modes of backwash to test the efficacy of the design on filtrate rate recovery for the different designs. The crossflow was 2,600 to 3,000 litres per hour except where otherwise indicated, using 1% weight for weight ferric hydroxide suspension.

The backwash modes used were:-

Backwash Type 1:-

Step 1 The lumens are drained of filtrate.
Step 2 The filter (with liquid on the feed side of the membranes and gas on the filtrate side of the membranes) is pressurised by applying gas pressure to the lumens, and the feed flow is shut off.
Step 3 The pressure on the feed side of the filter is released, and the gas pressure on the lumens is maintained, and meanwhile, the feed is left shut off.
Step 4 The feed flow is restarted while the gas pressure is maintained in the lumens to carry substantially all the accumulated detritus out of the filter.
Step 5 The gas pressure is removed from the filtrate side of the filter and filtrate allowed to refill the lumens.
Step 6 The filter is pressurised with the filtrate and feed exit shut either by pump pressure on the feed inlet or by shutting off the feed inlet and applying pressure to the filtrate line so as to replace the gas in the pores of the membrane with liquid.

Backwash Type 2:

Steps 1, 2 and 3 the same as Backwash Type 1, and then;
Step 4 The feed flow is restarted in the opposite direction to when the filter is used to filter feed, while the gas pressure is maintained in the lumens to carry substantially all the accumulated detritus out of the filter.
Steps 5 and 6 the same as Backwash Type 1.

Backwash Type 3:

Steps 1, 2 and 3 the same as Backwash Type 1, and then;
Step 4 The feed flow is restarted but with the direction of flow reversed at regular intervals with gas pressurisation of the lumens between reversals to carry substantially all the accumulated detritus out of the filter.
Steps 5 and 6 the same as Backwash Type 1.

A 1% weight for weight suspension of ferric hydroxide at 54°C was used as the feed with a crossflow of 2,600 to 3,000 litres per hour and a transmembrane pressure of 200 kilopascals. Each trial was for six minutes, and the results are tabulated below:-

Cartridge Type (as expressed in Fig.)	Backwash Type	Average filtrate flux over 6 minutes (l/hr)	Peak filtrate flux immediately after backwash (l/hr)
2	1	239	390
	2	340	580
	3	350	590
3	1	365	860
	2	384	920
	3	380	1110
4	1	375	710
	2	319	700
	3	429	1120
11	1	487	840
	2	456	680
	3	539	990
12	1	556	780
	2	591	930
	3	613	1050
10*	1	513	770
	2	447	800
	3	536	900

* The crossflow was 1,500 to 2,000 litres per hour in this case.

From the table, it can be readily seen that the Fig. 10 embodiment, which gave the best pressure drop results in Example 2, did not perform as well in terms of filtrate rate as the Fig. 12 embodiment. Whilst the prior art designs gave high peak recoveries of filtrate rate (column 4 of the above table), they did not perform as well on average as the filters of the present invention.

Claims

1. A filter unit comprising:

(i) an elongated open-ended casing (40,44,100) having transfer ports (50) adjacent each end (48) thereof to provide fluid communication between the outside and inside of the casing (40,44,100),

(ii) a bundle (43,101) of hollow, porous, polymeric fibres within the casing,

(iii) a first plug (49) at one end (45,48) of the casing in which one end of the bundle (43) of fibres is embedded whereby the plug (49) prevents flow of fluid out said one end (48) of the casing other than through the lumens of the fibres (43),

(iv) a second plug closing the other end (95) of the casing,

(v) a first transfer header (41,102) at said one end (45) of the casing and including:

a) a body portion (51) that encloses said one end of the casing,

b) a feed passageway (55) having an inlet (57,107) receiving feed to be treated,

d) an outlet chamber (63) for receiving filtrate from the open ends of the fibre lumens (43), and,

e) an outlet (67) for discharging filtrate,

(vi) a second transfer header (42,103) at the other end of the casing and including:

a) a body (51) portion that encloses said other end (95) of the casing (40,44,100),
b) an outlet chamber (107) for receiving treated feed, and
c) a treated feed passageway (72) for receiving treated feed characterised in that the feed passageway (55) extends through said first header (41), it has an inlet (57) at one end and an outlet (58) at the other end adapted to be connected to the inlet (57) of the feed passageway (55) of an adjacent first header (41) and a discharge port (59) for delivering feed to the casing (44),

an inlet chamber (53) is provided in fluid communication with the discharge port (59) of the feed passageway (55) and the transfer port (50) at said one end (48) of the casing,

a filtrate passageway (64) is provided extending through said first header (41) having a receiving port (66) for receiving filtrate from the outlet chamber (63), the outlet (67) for discharging filtrate located at one end of said passageway, and an inlet (68) at the other end adapted to be connected to the outlet (67) of the filtrate passageway (64) of an adjacent first header (41,102),

the outlet chamber (107) receives treated feed from a transfer port (50) at said other end (95) of the casing, and in that

the treated feed passageway (72) extends through said second header (42,103) and has an outlet (58) at one end for discharging treated feed from an outlet chamber (53) and an inlet (57) at the other end adapted to be connected to the outlet (58) of the feed passageway (72) of an adjacent second header.

2. A filter unit according to claim 1 wherein the second plug (49) cloning the other end (95) of the casing (44) has embedded therein the other end of the bundle of fibres (43) whereby the second plug prevents flow of fluid out said other end (95) of the casing other than through the lumens of the fibres (43) and wherein the second header (42) has an outlet chamber (63) receiving filtrate from the fibre lumens and a filtrate passageway (74) extending therethrough which has a receiving port (66) receiving filtrate from the outlet chamber (63) an outlet (67) at one end for discharging filtrate and an inlet (68) at the other end adapted to be connected to the outlet (67) of the filtrate passageway (74) of an adjacent second header.

3. A filter unit according to claim 1 or claim 2 wherein the first header (41) is a one-piece moulding.

4. A filter unit according to claim 1 or claim 2 wherein the second header (42) is a one-piece moulding and is identical to the first header (41).

5. A filter unit according to claim 1 or claim 2 wherein the first (41) and second (42) headers are releasably secured to the casing (40,44,100).

6. A filter unit according to claim 1 or claim 2 wherein the first (41) and second (42) headers are secured to the casing (40,44,100) to form an intergral cartridge.

7. A filter unit according to claim 1 or claim 2 wherein the feed passageway (55) is located in a first off-set portion (56) of the body (51) of the first header (41).

8. A filter unit according to claim 7 wherein the ends of the off-set portions (56) are planar and parallel.

9. A filter unit according to claim 1 or claim 2 wherein the treated feed passageway (72) is located in a first offset portion (73) of the body (51) of the second header (42).

10. A filter unit according to claim 9 wherein the ends of the off-set portions (73) are planar and parallel.

11. A filter unit according to any one of claims 7 to 10 and including a recess (60,69) around the inlet (57) or outlet (58) to each feed passageway for receiving an "O" ring (61).

12. A filter unit according to claim 9 and including a bevelled annular projection (62) at the other end of each passageway (55,72) adapted to engage the "O" ring (61) of an adjacent filter unit.

13. A filter unit according to claim 1 or claim 2 wherein the filtrate passageway (64) is located in a second off-set portion (65) of the first header (41).

14. A filter unit according to claim 13 and including a recess (69) around the inlet (68) or outlet (67) to each filtrate passageway (64)for receiving an "O" ring.

15. A filter unit according to claim 14 and including a bevelled annular projection (71) at the other end of each passageway (64) adapted to engage the "O" ring (70) of an adjacent filter unit (40,41,42).

16. A filter unit according to any one of the preceding claim wherein the casing (44,100) extends into the first (41) and second (42) header but terminates short of the transfer ports (50).

17. A filter unit according to any one of claims 1 to 15 wherein the casing (44,100) extends into the first (41) and second (42) header and beyond the nearer end of the transfer ports (50).

18. A filter unit according to any one of the preceding claims wherein the transfer ports (50) are elongate and extend parallel to the axis of the casing (44,100).

19. A filter unit according to any one of the preceding claims wherein the casing (40) includes a main tube (44) and an end portion (48) of each end of the main tube (44).

20. A filter unit according to claim 19 wherein the or each plug (49) is located in the end portion(s) (48) of the casing (40).

21. A filter unit according to claim 19 or claim 20 wherein annular grooves (94) are formed in the inner face of the end portion (95) of the casing (44) at the transfer ports (50).

22. A filter unit according to claim 21 wherein the grooves (94)are evenly spaced and extend across the transfer ports (50).

23. A filter unit according to claim 22 wherein the grooves (94)are of identical, uniform cross-section and intersect the transfer ports (50) at right angles to the axis of the transfer ports (50).

24. A bank (Fig-8) of filter units according to any one of the preceding claims wherein the filters are connected together by their headers (41,42) so that the feed passageways (55,72) and filtrate passageways (64,74) are connected in series whereby each filter may by supplied from the one source of feed with a portion of the feed being introduced into the inlet chamber (79,57) of each filter, the filtrate from each filter is directed to the interconnected filtrate passagewags (64,74) and the treated feed from each filter is directed to the interconnected treated feed passageways (72,84).

25. A bank of filter units (Fig.8) according to claim 24 wherein the units are connected together by bolt means (86,87,88,89) which force the units together whereby the respective bevelled annular projections (62,71) engage and compress the adjacent "O" rings (61,70).

26. A bank of filter units (Fig.8) according to claim 24 or claim 25 and including means (78,79) for introducing feed (A) into one end unit of the bank, means for introducing feed to the other end unit of the bank, means (83,85,80,81) for withdrawing filtrate (C,D) from at least one end unit of the bank and means (83,84) for withdrawing treated feed (B) from at least one end of the bank.

27. A bank of filter units (Fig.8) according to claim 26 wherein each unit (Fig.5) has a locating lug (76) on one side and a locating recepticle (77)on the other.

28. A method of operating a filter unit (Fig.5) according to claim 1 or a filter bank (Fig.8) according to claim 24 wherein the filter unit or bank is subjected to a backwash cycle in which:-

(i) the fibre lumens (43) are drained of filtrate,

(ii) the feed flow is terminated with feed remaining on the feed side of the filter and gas is applied to the lumens to pressurise the or each filter unit,

(iii)the pressure on the feed side of the filter is released whilst the gas pressure is maintained and there is no flow of feed,

(iv) flow of feed is resumed and gas pressure maintained in the lumens to carry substantially all of the accumulated detritus out of the filter,

(v) the gas pressure is removed from the filtrate side of the or each filter unit and filtrate allowed to refill the lumens,

(vi) the or each filter unit is pressurised so as to replace the gas in the pores of the membrane with liquid.

29. A method according to claim 28 wherein the or each filter unit is pressurised by closing the filtrate outlet (81,D) and treated feed outlet (84,B) and by applying pump pressure on the feed inlet (79,A).

30. A method according to claim 28 wherein the or each filter unit is pressurised by closing the filtrate outlet (81,D), feed inlet (79,A) and treated feed outlet and by applying pressure to the filtrate outlet.

31. A method according to claim 28 wherein the feed flow is restarted in the opposite direction to normal feed flow while the gas pressure is maintained in the lumens to carry substantially all of the accumulated detritus out of the filter.

32. A method according to claim 28 wherein the feed flow is restarted and its direction reversed at regular intervals while the gas pressure is maintained in the lumens between feed flow reversals to carry substantially all of the accumulated detritus out of the filter.

Patentansprüche

1. Filtereinheit, umfassend:

(i) ein langgestrecktes offenendiges Gehäuse (40, 44, 100), das Übergangskanäle (50) benachbart jedem Ende (48) desselben zum Erzielen einer Fluidverbindung zwischen dem Äußeren und dem Inneren des Gehäuses (40, 44, 100) hat,

(ii) ein Bündel (43, 101) von hohlen, porösen Polymerfasern innerhalb des Gehäuses,

(iii) einen ersten Stopfen (49) an einem Ende (45, 48) des Gehäuses, in welchem ein Ende des Bündels (43) von Fasern eingebettet ist, wodurch der Stopfen (49) eine Strömung von Fluid aus dem einen Ende (48) des Gehäuses in anderer Weise als durch die Hohlräume der Fasern (43) verhindert,

(iv) einen zweiten Stopfen, der das andere Ende (95) des Gehäuses verschließt,

(v) ein erstes Übertragungskopfstück (41, 102) an dem erwähnten einen Ende (45) des Gehäuses und umfassend:

a) einen Körperteil (51), der das erwähnte eine Ende des Gehäuses einschließt,

b) einen Beschickungskanal (55), der einen Einlaß (57, 107) für das Aufnehmen von zu behandelnder Beschickung hat,

d) eine Auslaßkammer (63) zum Aufnehmen von Filtrat aus den offenen Enden der Faserhohlräume (43), und

e) einen Auslaß (67) zum Entladen von Filtrat,

(vi) ein zweites Übergangskopfstück (42, 103) an dem anderen Ende des Gehäuses und umfassend:

a) einen Körper(51)teil, der das erwähnte andere Ende (95) des Gehäuses (40, 44, 100) umschließt,

b) eine Auslaßkammer (107) zum Aufnehmen von behandelter Beschickung, und

c) einen Behandelt-Beschickungskanal (72) zum Aufnehmen von behandelter Beschickung, dadurch **gekennzeichnet**, daß sich der Beschickungskanal (55) durch das erste Kopfstück (41) erstreckt, er einen Einlaß (57) an einem Ende und einen Auslaß (58) an dem anderen Ende, der geeignet ist, mit dem Einlaß (57) des Beschickungskanals (55) eines benachbarten ersten Kopfstücks (41) verbunden zu werden, und einen Entladungsdurchgang (59) zum Abgeben von Beschickung zu dem Gehäuse (44), hat,

eine Einlaßkammer (53) in Fluidverbindung mit dem Entladungsdurchgang (59) des Beschickungskanals (55) und dem Übergangskanal (50) an dem erwähnten einen Ende (48) des Gehäuses vorgesehen ist,

ein Filtratkanal (64) vorgesehen ist, der sich durch das erste Kopfstück (41) erstreckt und einen Aufnahmedurchgang (66) für das Aufnehmen von Filtrat aus der Auslaßkammer (63) hat, wobei sich der Auslaß (67) zum Entladen von Filtrat an einem Ende des erwähnten Kanals befindet, sowie einen Einlaß (68) am anderen Ende hat, der dazu geeignet ist, mit dem Auslaß (67) des Filtratkanals (64) eines benachbarten ersten Kopfstücks (41, 102) verbunden zu werden,

die Auslaßkammer (107) behandelte Beschickung aus einem Übergangskanal (50) an dem anderen Ende (95) des Gehäuses aufnimmt, und daß

sich der Behandelt-Beschickungskanal (72) durch das zweite Kopfstück (42, 103) erstreckt und einen Auslaß (58) an einem Ende zum Entladen von behandelter Beschickung aus einer Auslaßkammer (53), und einen Einlaß (57) an dem anderen Ende, der dazu geeignet ist, mit dem Auslaß (58) des Beschickungskanals (72) eines benachbarten zweiten Kopfstücks verbunden zu werden, hat.

2. Filtereinheit nach Anspruch 1, worin in dem zweiten Stopfen (49), der das andere Ende (95) des Gehäuses (44) verschließt, das andere Ende des Bündels von Fasern (43) eingebettet ist, wodurch der zweite Stopfen eine Strömung von Fluid aus dem erwähnten anderen Ende (95) des Gehäuses in anderer Weise als durch die Hohlräume der Fasern (43) verhindert, und worin das zweite Kopfstück (42) eine Auslaßkammer (63) zum Aufnehmen von Filtrat aus den Faserhohlräumen hat, und einen sich durch dasselbe hindurch erstreckenden Filtratkanal (74), der einen Aufnahmedurchgang (66) zum Aufnehmen von Filtrat aus der Auslaßkammer (63), sowie einen Auslaß (67) an einem Ende zum Entladen von Filtrat und einen Einlaß (68) an dem anderen Ende, der dazu geeignet ist, mit dem Auslaß (67) des Filtratkanals (74) eines benachbarten zweiten Kopfstücks verbunden zu werden. hat.

3. Filtereinheit nach Anspruch 1 oder Anspruch 2, worin das erste Kopfstück (41) ein einstückiger Formling ist.

4. Filtereinheit nach Anspruch 1 oder Anspruch 2, worin das zweite Kopfstück (42) ein einstückiger Formling und identisch mit dem ersten Kopfstück (41) ist.

5. Filtereinheit nach Anspruch 1 oder Anspruch 2, worin das erste (41) und zweite (42) Kopfstück lösbar an dem Gehäuse (40, 44, 100) befestigt sind.

6. Filtereinheit nach Anspruch 1 oder Anspruch 2, worin das erste (41) und zweite (42) Kopfstück zur Ausbildung einer integralen Patrone an dem Gehäuse (40, 44, 100) befestigt sind.

7. Filtereinheit nach Anspruch 1 oder Anspruch 2, worin sich der Beschickungskanal (55) in einem ersten abgesetzten Teil (56) des Körpers (51) des ersten Kopfstücks (41) befindet.

8. Filtereinheit nach Anspruch 7, worin die Enden der abgesetzten Teile (56) planar und parallel sind.

9. Filtereinheit nach Anspruch 1 oder Anspruch 2, worin sich der Behandelt-Beschickungskanal (72) in einem ersten abgesetzten Teil (73) des Körpers (51) des zweiten Kopfstücks (42) befindet.

10. Filtereinheit nach Anspruch 9, worin die Enden der abgesetzten Teile (73) planar und parallel sind.

11. Filtereinheit nach irgendeinem der Ansprüche 7 bis 10 und umfassend eine Ausnehmung (60, 69) um den Einlaß (57) oder Auslaß (58) zu jedem Beschickungskanal herum für die Aufnahme eines "O"-Rings (61).

12. Filtereinheit nach Anspruch 9 und umfassend einen konischen bzw. verjüngten ringförmigen Vorsprung (62) an dem anderen Ende von jedem Kanal (55, 72), der dazu geeignet ist, mit dem "O"-Ring (61) einer benachbarten Filtereinheit in Eingriff zu treten.

13. Filtereinheit nach Anspruch 1 oder Anspruch 2, worin sich der Filtratkanal (64) in einem zweiten abge-

setzten Teil (65) des ersten Kopfstücks (41) befindet.

14. Filtereinheit nach Anspruch 13 und umfassend eine Ausnehmung (69) um den Einlaß (68) oder Auslaß (67) zu jedem Filtratkanal (64) herum zur Aufnahme eines "O"-Rings.

15. Filtereinheit nach Anspruch 14 und umfassend einen konischen bzw. verjüngten ringförmigen Vorsprung (71) an dem anderen Ende von jedem Kanal (64), der dazu geeignet ist, mit dem "O"-Ring (70) einer benachbarten Filtereinheit (40, 41, 42) in Eingriff zu treten.

16. Filtereinheit nach irgendeinem der vorhergehenden Ansprüche, worin sich das Gehäuse (44, 100) in das erste (41) und zweite (42) Kopfstück erstreckt, jedoch kurz vor den Übergangskanälen (50) endet.

17. Filtereinheit nach irgendeinem der Ansprüche 1 bis 15, worin sich das Gehäuse (44, 100) in das erste (41) und zweite (42) Kopfstück und über das nähere Ende der Übergangskanäle (50) hinaus erstreckt.

18. Filtereinheit nach irgendeinem der vorhergehenden Ansprüche, worin die Übergangskanäle (50) langgestreckt sind und sich parallel zu der Achse des Gehäuses (44, 100) erstrecken.

19. Filtereinheit nach irgendeinem der vorhergehenden Ansprüche, worin das Gehäuse (40) ein Hauptrohr (44) und einen Endteil (48) von jedem Ende des Hauptrohrs (44) umfaßt.

20. Filtereinheit nach Anspruch 19, worin sich der oder jeder Stopfen (49) in dem Endteil bzw. in den Endteilen (48) des Gehäuses (40) befindet.

21. Filtereinheit nach Anspruch 19 oder Anspruch 20, worin ringförmige Ausnehmungen (94) in der inneren Fläche des Endteils (95) des Gehäuses (44) an den Übergangskanälen (50) ausgebildet sind.

22. Filtereinheit nach Anspruch 21, worin die Ausnehmungen (94) gleichförmig beabstandet sind und sich über die Übergangskanäle (50) erstrecken.

23. Filtereinheit nach Anspruch 22, worin die Ausnehmungen (94) von identischem, gleichförmigem Querschnitt sind und die Übergangskanäle (50) rechtwinklig zu der Achse der Übergangskanäle (50) schneiden.

24. Bank (Fig. 8) von Filtereinheiten gemäß irgendeinem der vorhergehenden Ansprüche, worin die Filter durch ihre Kopfstücke (41, 42) miteinander so verbunden sind, daß die Beschikkungskanäle (55, 72) und Filtratkanäle (64, 74) in Reihe verbunden sind, wodurch jedes Filter von der einen Beschickungsquelle versorgt werden kann, wobei ein Teil der Beschickung in die Einlaßkammer (79, 57) von jedem Filter eingeführt wird, wobei das Filtrat von jedem Filter zu den miteinanderverbundenen Filtratkanälen (64, 74) geleitet wird und die behandelte Beschickung von jedem Filter zu den miteinander verbundenen Behandelt-Beschickungskanälen (72, 84) geleitet wird.

25. Bank von Filtereinheiten (Fig. 8) nach Anspruch 24, worin die Einheiten durch Bolzen- bzw. Schraubenmittel (86, 87, 88, 89) miteinander verbunden sind, welche die Einheiten zusammendrücken, wodurch die jeweiligen konischen bzw. verjüngten ringförmigen Vorsprünge (62, 71) mit den benachbarten "O"-Ringen (61, 70) in Eingriff treten und diese zusammendrücken.

26. Bank von Filtereinheiten (Fig. 8) nach Anspruch 24 oder Anspruch 25 und umfassend eine Einrichtung (78, 79) zum Einführen von Beschickung (A) in eine Endeinheit der Bank, eine Einrichtung zum Einführen von Beschickung zu der anderen Endeinheit der Bank, eine Einrichtung (83, 85, 80, 81) zum Abziehen von Filtrat (C, D) von wenigstens einer Endeinheit der Bank und eine Einrichtung (83, 84) zum Abziehen von behandelter Beschickung (B) aus wenigstens einem Ende der Bank.

27. Bank von Filtereinheiten (Fig. 8) nach Anspruch 26, worin jede Einheit (Fig. 5) einen Lokalisierungsansatz (76) auf einer Seite und eine Lokalisierungsaufnahme (77) auf der anderen hat.

28. Verfahren zum Betreiben einer Filtereinheit (Fig. 5) gemäß Anspruch 1 oder einer Filterbank (Fig. 8) gemäß Anspruch 24, worin die Filtereinheit oder -bank einem Rückwäschezyklus ausgesetzt wird, in welchem:

(i) die Faserhohlräume (43) von Filtrat entleert werden,

(ii) die Beschickungsströmung beendet wird, wobei Beschikkung auf der Beschickungsseite des Filters bleibt, und Gas auf die Hohlräume angewandt wird, um die oder jede Filtereinheit unter Druck zu setzen,

(iii) der Druck auf der Beschickungsseite des Filters entspannt wird, während der Gasdruck aufrechterhalten wird und keine Strömung von Beschickung vorhanden ist,

(iv) die Strömung der Beschickung wiederaufgenommen wird und Gasdruck in den Hohlräumen aufrechterhalten wird, um im wesentlichen allen angesammelten Schutt aus dem Filter zu tragen,

(v) der Gasdruck von der Filtratseite von der oder jeder Filtereinheit weggenommen und es dem Filtrat ermöglicht wird, die Hohlräume wieder zu füllen,

(vi) die oder jede Filtereinheit so unter Druck gesetzt wird, daß das Gas in den Poren der Membrane durch Flüssigkeit ersetzt wird.

29. Verfahren nach Anspruch 28, worin die oder jede Filtereinheit durch Schließen des Filtratauslasses (81, D) und des Behandelt-Beschickungsauslasses (84, B) und durch Anwendung von Pumpendruck auf den Beschickungseinlaß (79, A) unter Druck gesetzt wird.

30. Verfahren nach Anspruch 28, worin die oder jede Filtereinheit durch Schließen des Filtratauslasses (81, D), des Beschickungseinlasses (79, A) und des Behandelt-Beschickungsauslasses und durch Anwendung

von Druck auf den Filtratauslaß unter Druck gesetzt wird.

31. Verfahren nach Anspruch 28, worin die Beschickungsströmung in der entgegengesetzten Richtung zur normalen Beschickungsströmung erneut gestartet wird, während der Gasdruck in den Hohlräumen aufrechterhalten wird, um im wesentlichen allen angesammelten Schutt aus dem Filter zu tragen.

32. Verfahren nach Anspruch 28, worin die Beschickungsströmung erneut gestartet und ihre Richtung umgekehrt wird, und zwar in regelmäßigen Intervallen, während der Gasdruck in den Hohlräumen zwischen den Beschickungsströmungsumkehrungen aufrechterhalten wird, um im wesentlichen allen angesammelten Schutt aus dem Filter zu tragen.

Revendications

1. Unité de filtre comprenant :

(i) un boîtier allongé (40,44,100) ouvert aux extrémités comportant des orifices de transfert (50) adjacents à chacune de ses extrémités (48) pour établir une communication par fluide entre l'extérieur et l'intérieur du boîtier (40,44,100),

(ii) un faisceau (43,101) de fibres creuses polymériques poreuses à l'intérieur du boîtier,

(iii) un premier bouchon (49) à une extrémité (45,48) du boîtier dans lequel est noyé une extrémité du faisceau (43) de fibres de sorte que le bouchon (49) empêche le fluide de s'écouler hors de ladite extrémité (48) du boîtier autrement que par les ouvertures de fibres (43),

(iv) un second bouchon qui ferme l'autre extrémité (95) du boîtier,

(v) un premier élément extrême de transfert (41,102) à une extrémité (45) du boîtier et comprenant :

a) une partie formant corps (51) qui entoure ladite extrémité du boîtier,

b) un passage (55) pour la charge comportant une entrée (57,107) recevant la charge à traiter,

d) une chambre de sortie (63) destinée à recevoir le filtrat provenant des extrémités ouvertes des ouvertures des fibres (43), et

e) une sortie (67) pour l'évacuation du filtrat,

(vi) un second élément extrême de transfert (42,103) à l'autre extrémité du boîtier et comprenant :

a) une partie formant corps (51) qui entoure l'autre extrémité (95) du boîtier (40,44,100),

b) une chambre de sortie (107) destinée à recevoir la charge traitée, et

c) un passage (72) pour la charge traitée destiné à recevoir la charge traitée, caractérisée en ce que le passage (55) pour la charge s'étend à travers ledit premier élément extrême (41), comporte une entrée (57) à une extrémité et une sortie (58) à l'autre extrémité destinée à être reliée à l'entrée (57) du passage (55) pour la charge d'un premier élément extrême (41) adjacent et un orifice d'évacuation (59) pour envoyer la charge dans le boîtier (44),

une chambre d'entrée (53) est en communication par fluide avec l'orifice d'évacuation (59) du passage (55) pour la charge et l'orifice de transfert (50) à ladite extrémité (48) du boîtier,

un passage (64) pour le filtrat s'étend à travers le premier élément extrême (41) et comporte un orifice de réception (66) destiné à recevoir le filtrat provenant de la chambre de sortie (63), la sortie (67) pour évacuer le filtrat située à une extrémité dudit passage, et une entrée (68) à l'autre extrémité conçue pour être reliée à la sortie (67) du passage (64) pour le filtrat d'un premier élément extrême (41,102) adjacent,

la chambre de sortie (107) reçoit la charge traitée provenant d'un orifice de transfert (50) à l'autre extrémité (95) du boîtier, et ce que

le passage (72) pour la charge traitée s'étend à travers ledit second élément extrême (42,103) et comporte une sortie (58) à une extrémité pour évacuer la charge traitée provenant d'une chambre de sortie (53) et une entrée (57) à l'autre extrémité conçue pour être reliée à la sortie (58) du passage (72) pour la charge d'un second élément extrême adjacent.

2. Unité de filtre selon la revendication 1, dans laquelle l'autre extrémité du faisceau de fibres (43) est noyée dans le second bouchon (49) qui ferme l'autre extrémité (95) du boîtier (44) de sorte que le second bouchon empêche le fluide de s'écouler hors de ladite autre extrémité (95) du boîtier autrement que par les ouvertures des fibres (43) et dans laquelle le second élément extrême (42) comporte une chambre de sortie (63) qui reçoit le filtrat provenant des ouvertures des fibres et un passage (74) pour le filtrat qui le traverse et qui comporte un orifice de réception (66) pour recevoir le filtrat provenant de la chambre de sortie (63), une sortie (67) à une extrémité pour évacuer le filtrat et une entrée (68) à l'autre extrémité conçue pour être reliée à la sortie (67) du passage (74) pour le filtrat d'un second élément extrême adjacent.

3. Unité de filtre selon la revendication 1 ou la revendication 2, dans laquelle le premier élément extrême (41) est un moulage d'une seule pièce.

4. Unité de filtre selon la revendication 1 ou la revendication 2, dans laquelle le second élément extrême (42) est un moulage d'une seule pièce identique au premier élément extrême (41).

5. Unité de filtre selon la revendication 1 ou la revendication 2, dans laquelle les premier (41) et second (42) éléments extrêmes sont fixés de manière détachable au boîtier (40,44,100).

6. Unité de filtre selon la revendication 1 ou la revendication 2, dans laquelle les premier (41) et second (42) éléments extrêmes sont fixés au boîtier (40,44,100) pour former une cartouche monobloc.

7. Unité de filtre selon la revendication 1 ou la revendication 2 dans laquelle le passage (55) pour la charge est situé dans une première partie décalée (56) du corps (51) du premier élément extrême (41).

8. Unité de filtre selon la revendication 7, dans laquelle les extrémités des parties décalées (56) sont planes et parallèles.

9. Unité de filtre selon la revendication 1 ou la revendication 2, dans laquelle le passage (72) pour la charge traitée est situé dans une première partie décalée (73) du corps (51) du second élément extrême (42).

10. Unité de filtre selon la revendication 9, dans laquelle les extrémités des parties décalées (73) sont planes et parallèles.

11. Unité de filtre selon l'une quelconque des revendications 7 à 10 comprenant un évidement (60,69) autour de l'entrée (57) ou de la sortie (58) de chaque passage pour la charge, destiné à recevoir un joint torique (61).

12. Unité de filtre selon la revendication 9, comprenant une saillie annulaire biseautée (62) à l'autre extrémité de chaque passage (55,72) conçue pour coopérer avec le joint torique (61) d'une unité de filtre adjacente.

13. Unité de filtre selon la revendication 1 ou la revendication 2, dans laquelle le passage (64) pour le filtrat est situé dans une seconde partie décalée (65) du premier élément extrême (41).

14. Unité de filtre selon la revendication 13, comprenant un évidement (69) autour de l'entrée (68) ou de la sortie (67) de chaque passage (64) pour le filtrat, destiné à recevoir un joint torique.

15. Unité de filtre selon la revendication 14, comprenant une saille annulaire biseautée (71) à l'autre extrémité de chaque passage (64) destinée à coopérer avec le joint torique (70) d'une unité de filtre adjacente (40,41,42).

16. Unité de filtre selon l'une quelconque des revendications précédentes, dans laquelle le boîtier (44,100) s'étend dans le premier élément extrême (41) et dans le second élément extrême (42) mais se termine à peu de distance des orifices de transfert (50).

17. Unité de filtre selon l'une quelconque des revendications 1 à 15, dans laquelle le boîtier (44,100) s'étend dans le premier élément extrême (41) et dans le second élément extrême (42) et au-delà de l'extrémité la plus proche des orifices de transfert (50).

18. Unité de filtre selon l'une quelconque des revendications précédentes, dans laquelle les orifices de transfert (50) sont allongés et s'étendent parallèlement à l'axe du boîtier (44,100).

19. Unité de filtre selon l'une quelconque des revendications précédentes, dans laquelle le boîtier (40) comprend un tube principal (44) et une partie extrême (48) de chaque extrémité du tube principal (44).

20. Unité de filtre selon la revendication 19, dans laquelle le ou chaque bouchon (49) est situé dans la ou les parties extrêmes (48) du boîtier (40).

21. Unité de filtre selon la revendication 19 ou la revendication 20, dans laquelle des rainures annulaires (94) sont formées dans la face interne de la partie extrême (95) du boîtier (44) au niveau des orifices de transfert (50).

22. Unité de filtre selon la revendication 21, dans laquelle les rainures (94) sont écartées uniformément et s'étendent sur les orifices de transfert (50).

23. Unité de filtre selon la revendication 22, dans laquelle les rainures (94) sont de section transversale uniforme identique et coupent les orifices de transfert (50) à angle droit par rapport à l'axe des orifices de transfert (50).

24. Batterie (figure 8) d'unités de filtre selon l'une quelconque des revendications précédentes dans laquelle les filtres sont reliés entre eux par leurs éléments extrêmes (41,42) de sorte que les passages (55,72) pour la charge et les passages (64,74) pour le filtrat sont reliés en série si bien que chaque filtre peut être alimenté en charge depuis une source, une partie de la charge étant introduite dans la chambre d'entrée (79,57) de chaque filtre, le filtrat provenant de chaque filtre est envoyé dans les passages (64,74) pour le filtrat qui sont reliés entre eux et la charge traitée provenant de chaaque filtre est envoyée dans les passages (72,84) pour la chage traitée qui sont reliés entre eux.

25. Batterie d'unités de filtre (figure 8) selon la revendication 24, dans laquelle les unités sont reliées entre elles par des boulons (86,87,88,89) qui serrent les unités ensemble de sorte que les saillies annulaires biseautées (62,71) respectives coopèrent et compriment les joints toriques (61,70) adjacents.

26. Batterie d'unités de filtre (figure 8) selon la revendication 24 ou la revendication 25, comprenant des moyens (78,79) pour introduire la charge (A) dans une unité extrême de la batterie, des moyens pour introduire

la charge dans l'autre unité extrême de la batterie, des moyens (83,85,80,81) pour retirer le filtrat (C,D) d'au moins une unité extrême de la batterie et des moyens (83,84) pour retirer la charge traitée (B) d'au moins une extrémité de la batterie.

27. Batterie d'unités de filtre (figure 8) selon la revendication 26, dans laquelle chaque unité (figure 5) comporte un tenon de positionnement (76) sur un côté et un logement de positionnement (77) sur l'autre côté.

28. Procédé d'exploitation d'une unité de filtre (figure 5) selon la revendication 1 ou d'une batterie de filtres (figure 8) selon la revendication 24, dans lequel l'unité de filtre ou la batterie de filtres est soumise à un cycle de lavage par inversion du courant dans lequel :

(i) les ouvertures de fibres (43) sont débarrassées du filtrat,

(ii) l'écoulement de charge se termine par la charge qui reste du côté charge du filtre et un gaz est appliqué aux ouvetures pour mettre sous pression l'unité de filtre ou chaque unité de filtre,

(iii) la pression du côté charge du filtre est supprimée tandis que la pression de gaz est maintenue et qu'il n'y a pas d'écoulement de charge,

(iv) l'écoulement de la charge est rétabli et la pression de gaz est maintenue dans les ouvertures pour entraîner hors du filtre sensiblement la totalité des détritus accumulés,

(v) la pression de gaz est supprimée du côté du filtrat de l'unité de filtre ou de chaque unité de filtre et le filtrat est amené à remplir de nouveau les ouvertures,

(vi) la ou chaque unité de filtre est mise sous pression de manière à remplacer le gaz dans les pores de la membrane par du liquide.

29. Procédé selon la revendication 28, dans lequel la ou chaque unité de filtre est mise sous pression par fermeture de la sortie (81,D) pour le filtrat et de la sortie (84,B) pour la charge traitée et par application d'une pression de pompe sur l'entrée (79,A) pour la charge.

30. Procédé selon la revendication 28, dans lequel la ou chaque unité de filtre est mise sous pression par fermeture de la sortie (81,D) pour le filtrat, de l'entrée (79,A) pour la charge et de la sortie pour la charge traitée et par application d'une pression à la sortie pour le filtrat.

31. Procédé selon la revendication 28, dans lequel l'écoulement de charge est rétabli dans la direction opposée à l'écoulement normal de la charge tandis que la pression de gaz est maintenue dans les ouvertures pour entraîner hors du filtre sensiblement la totalité des détritus accumulés.

32. Procédé selon la revendication 28, dans lequel l'écoulement de charge est rétabli et sa direction est inversée à intervalles réguliers tandis que la pression de gaz est maintenue dans les ouvertures entre les inversions d'écoulement de la charge pour entraîner hors du filtre sensiblement la totalité des détritus accumulés.

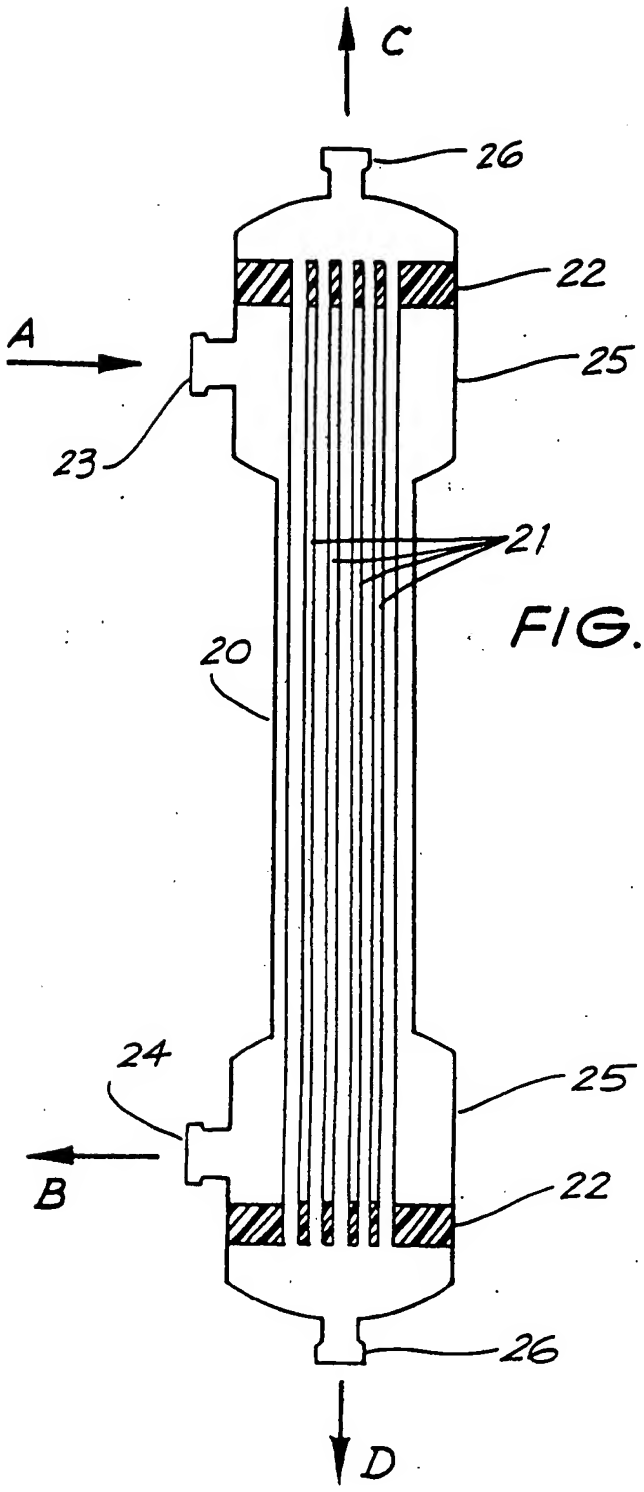


FIG. 1

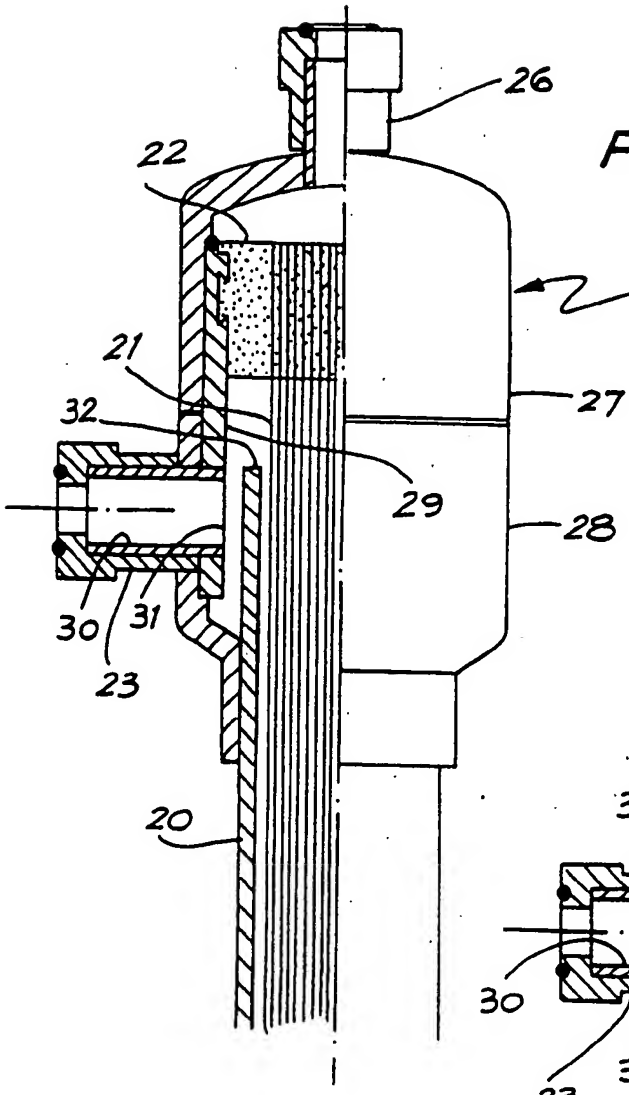


FIG. 2

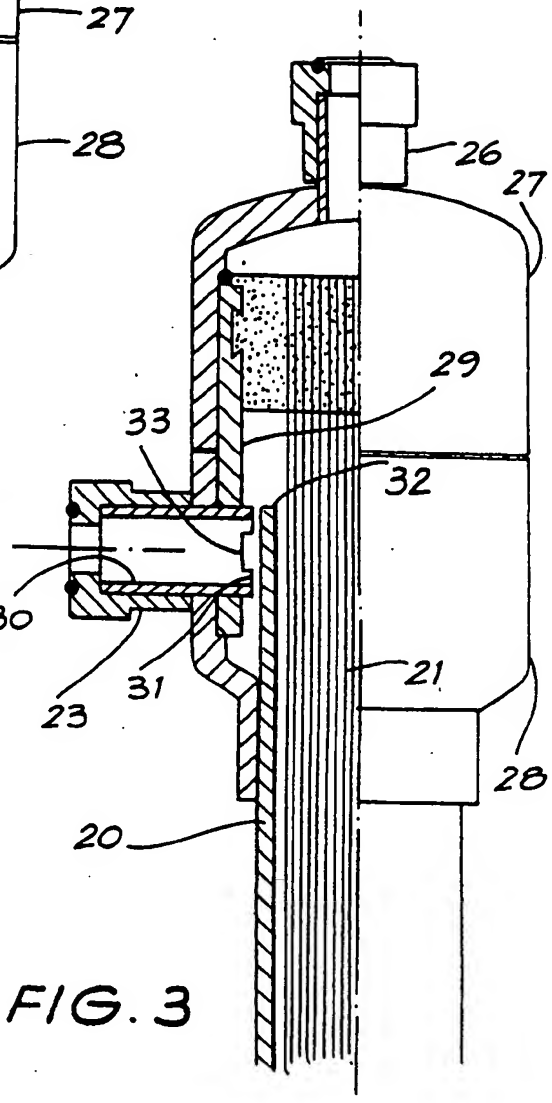


FIG. 3

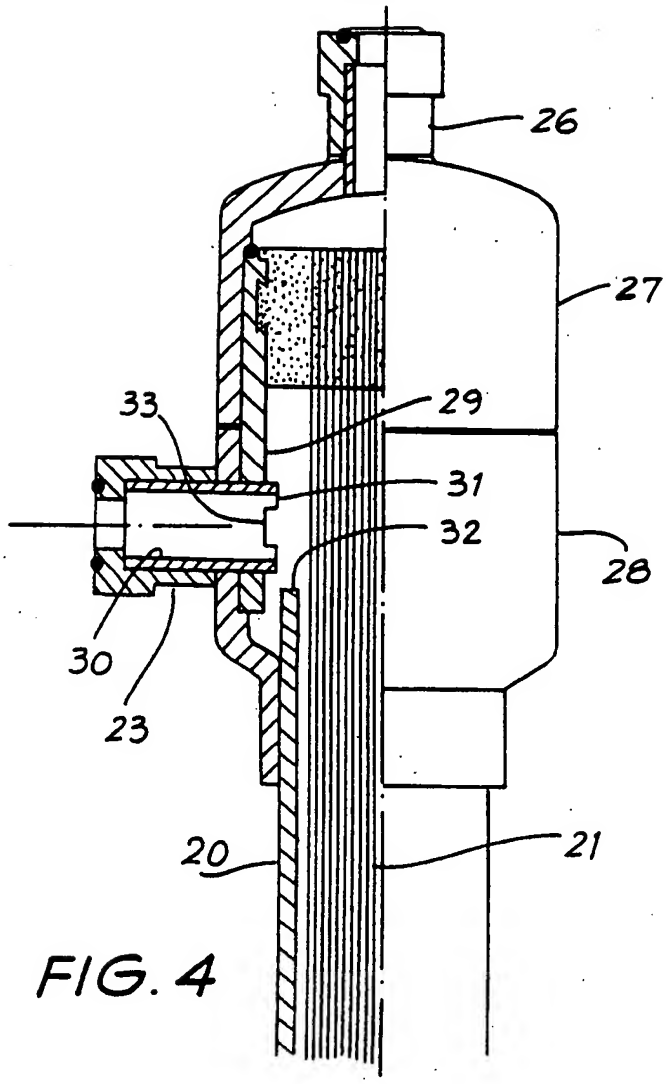


FIG. 4

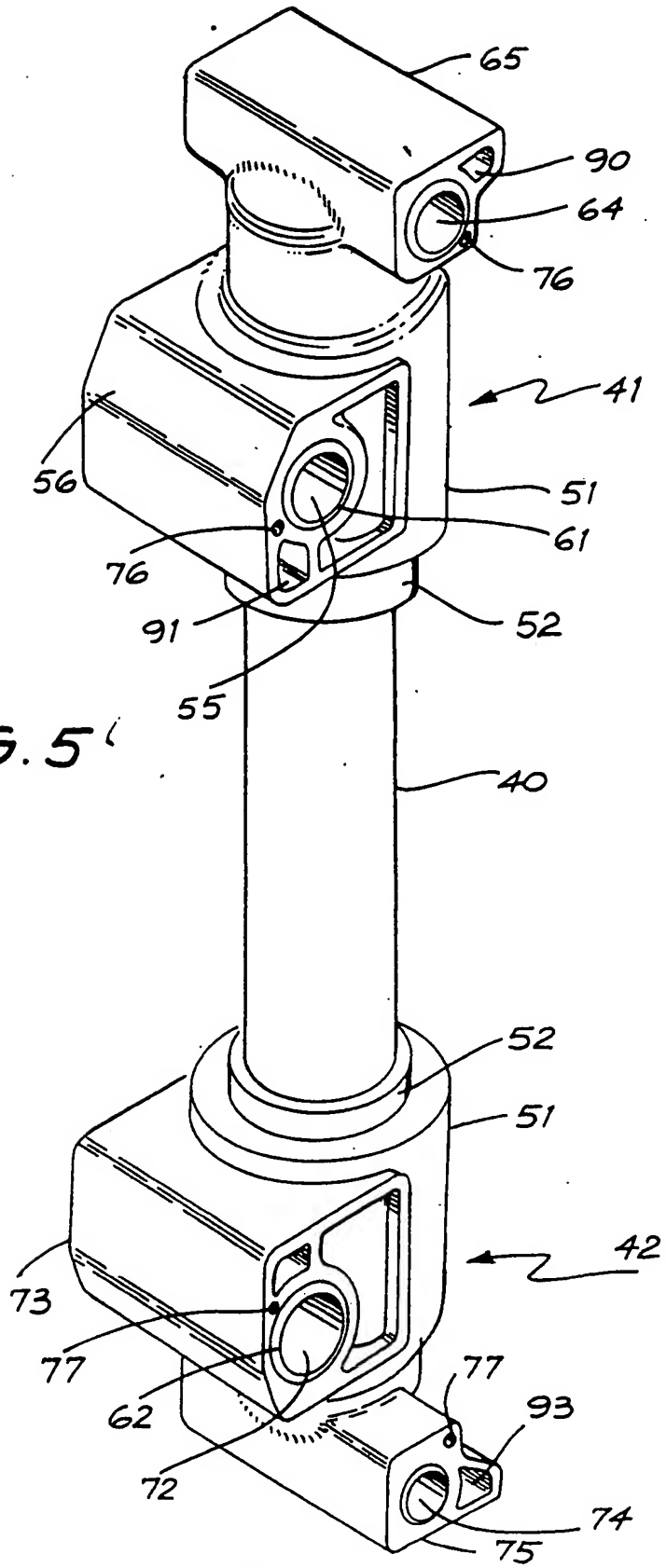


FIG. 5

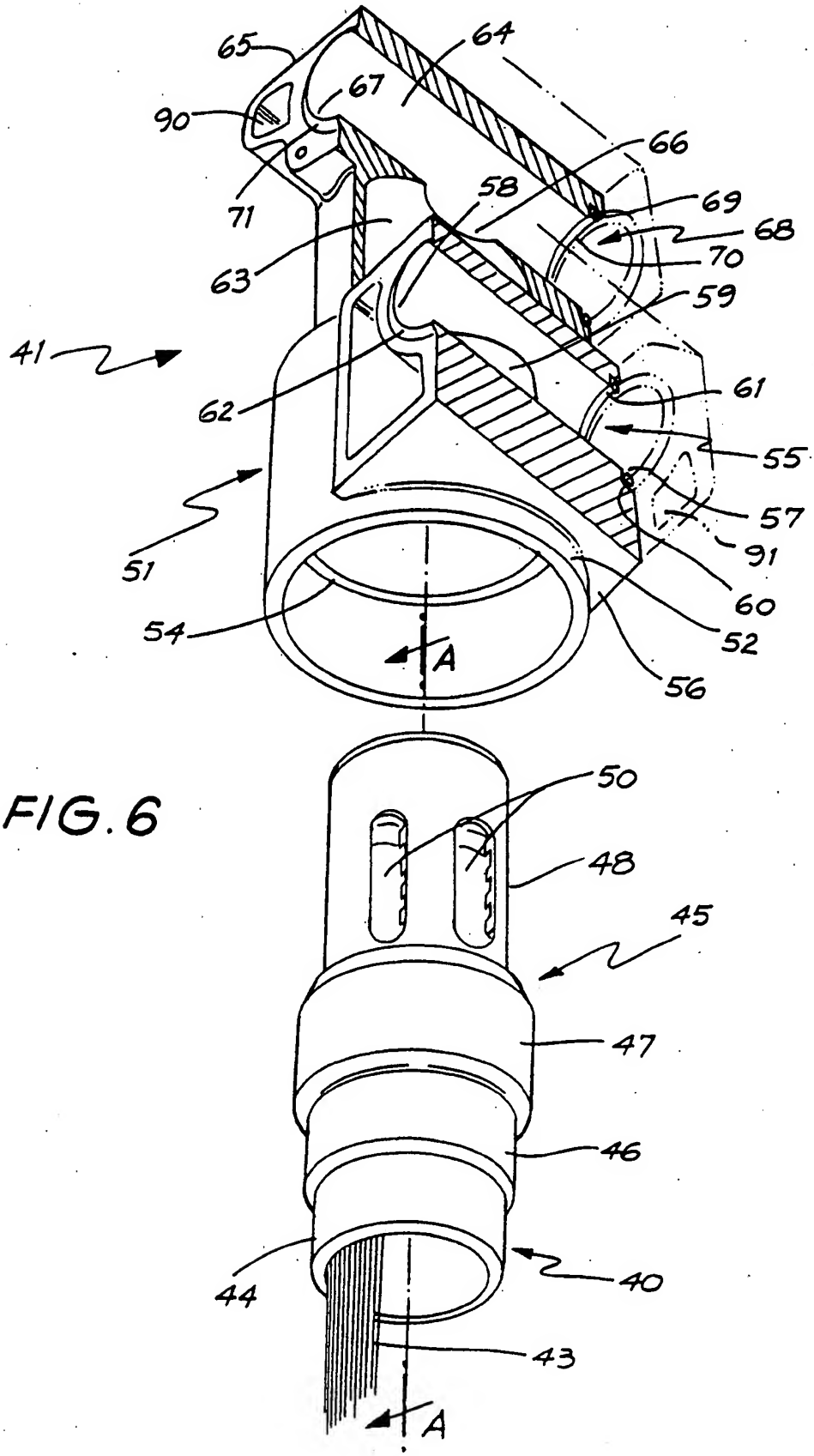

65
64
67
90
66
71
58
69
68
63
70
59
41
61
62
55
57
51
91
60
54
52
A
56
50
48
45
47
46
44
40
43
A

FIG. 6

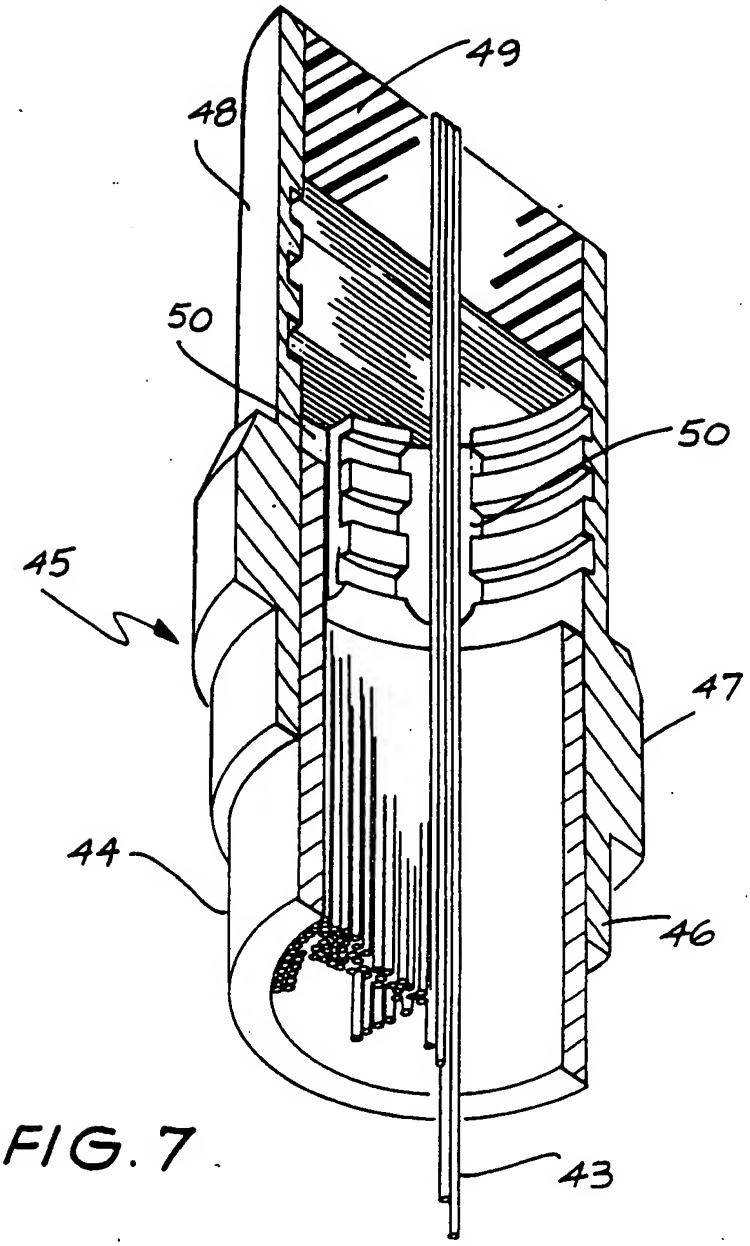
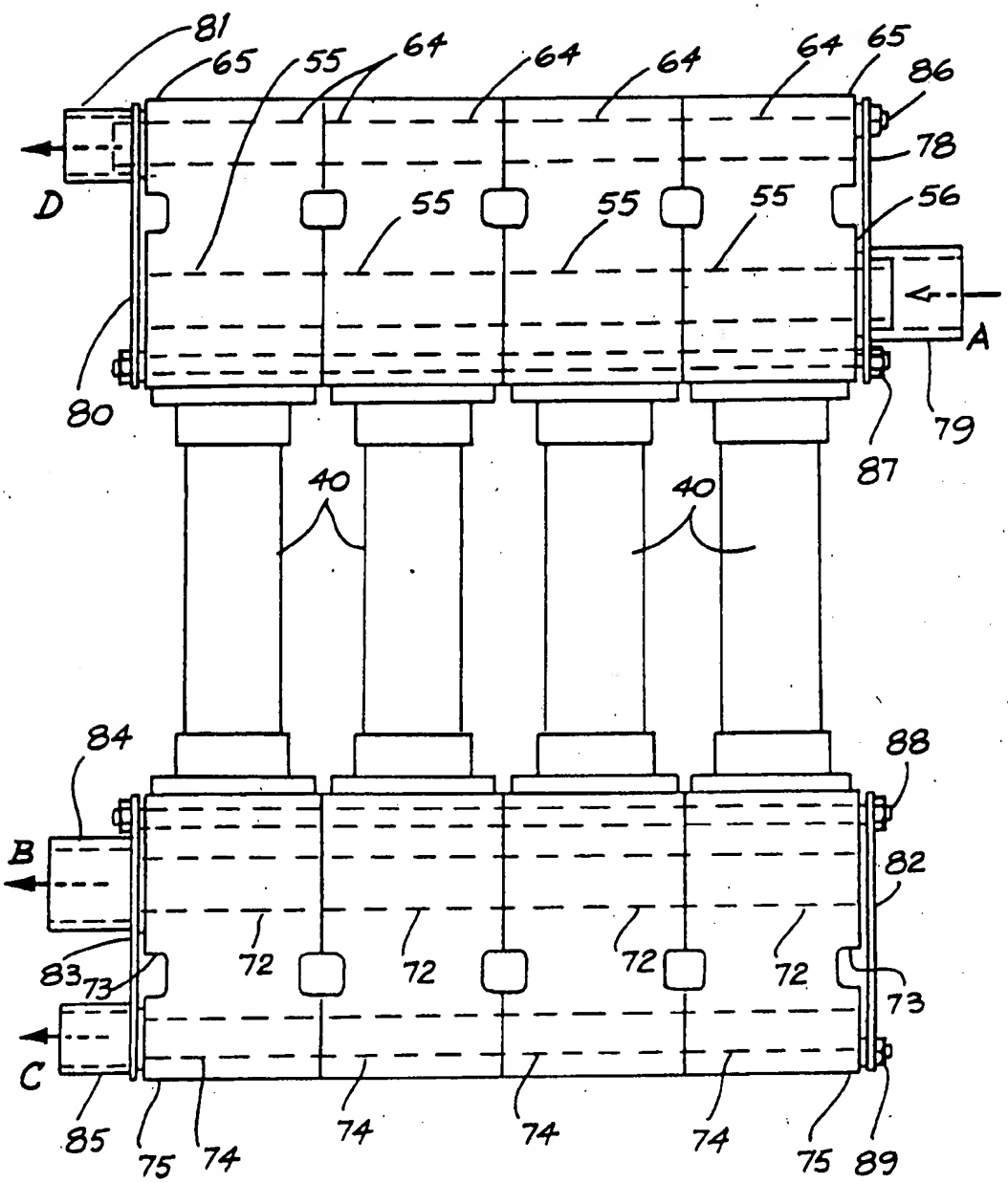


FIG. 7


81
65
55
64
64
64
64
65
86
78
D
55
55
55
56
A
80
79
87
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40
84
88
B
82
72
72
72
72
83
73
73
C
85
75
74
74
74
74
75
89

FIG. 8

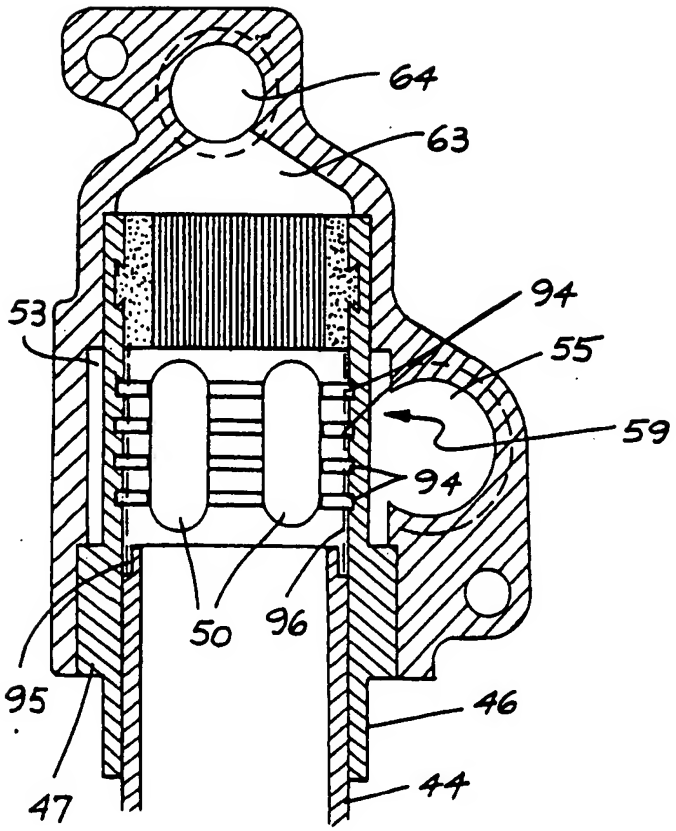


FIG. 9

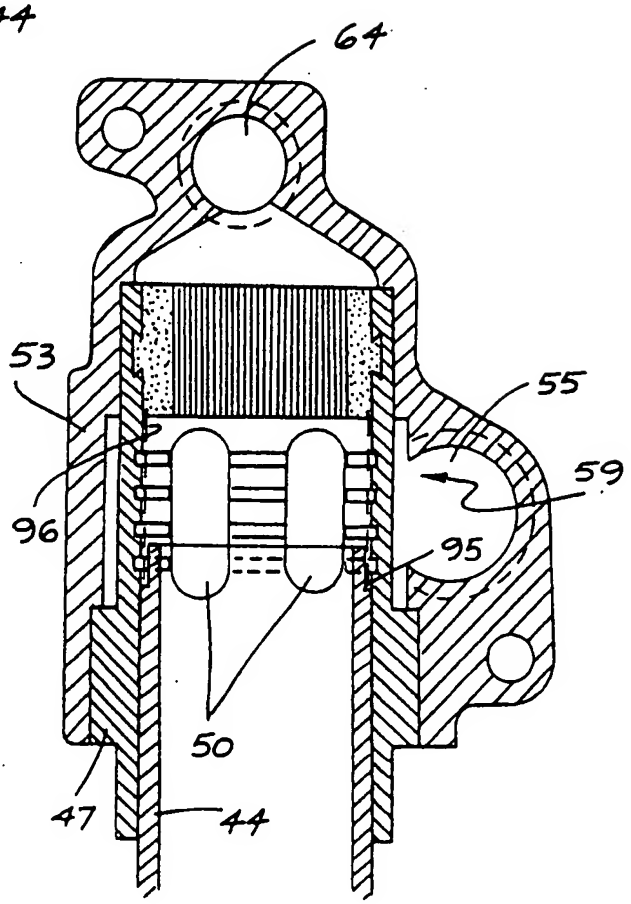


FIG. 10

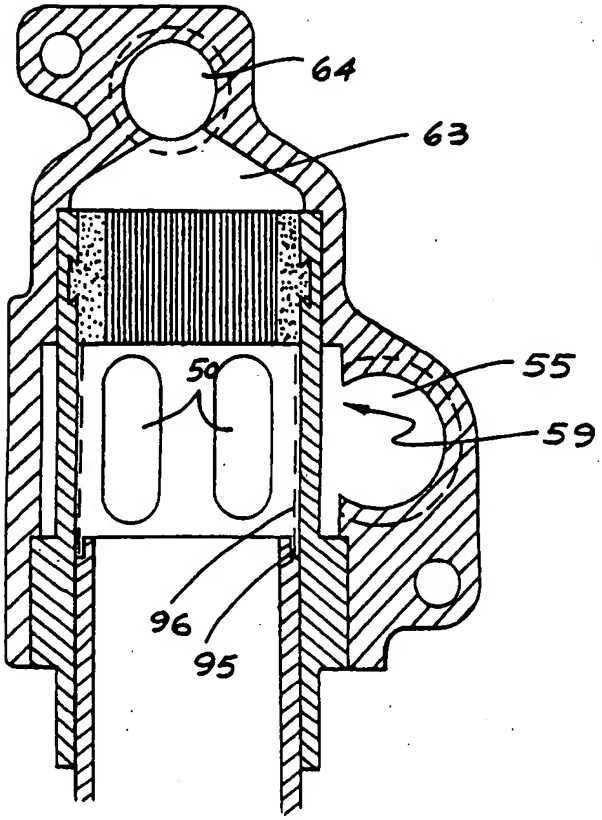


FIG. 11

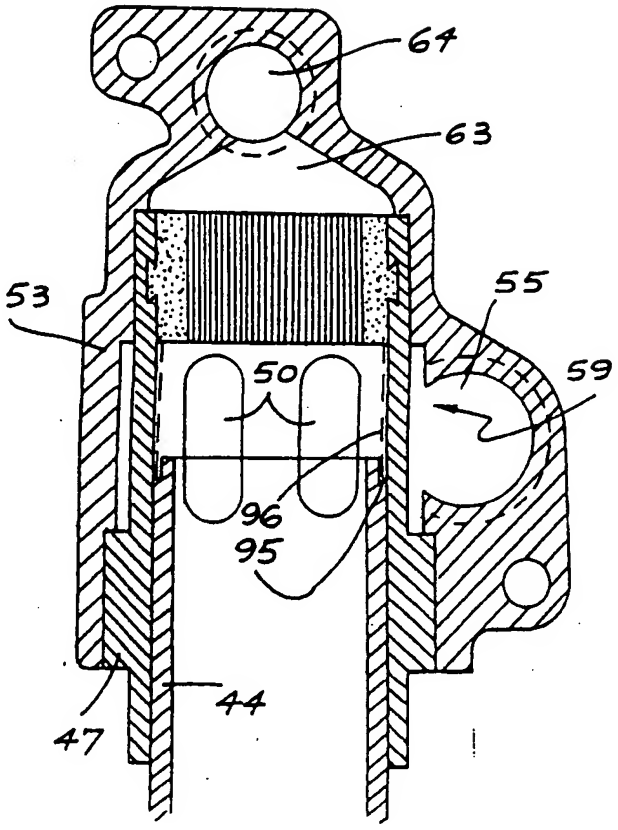


FIG. 12

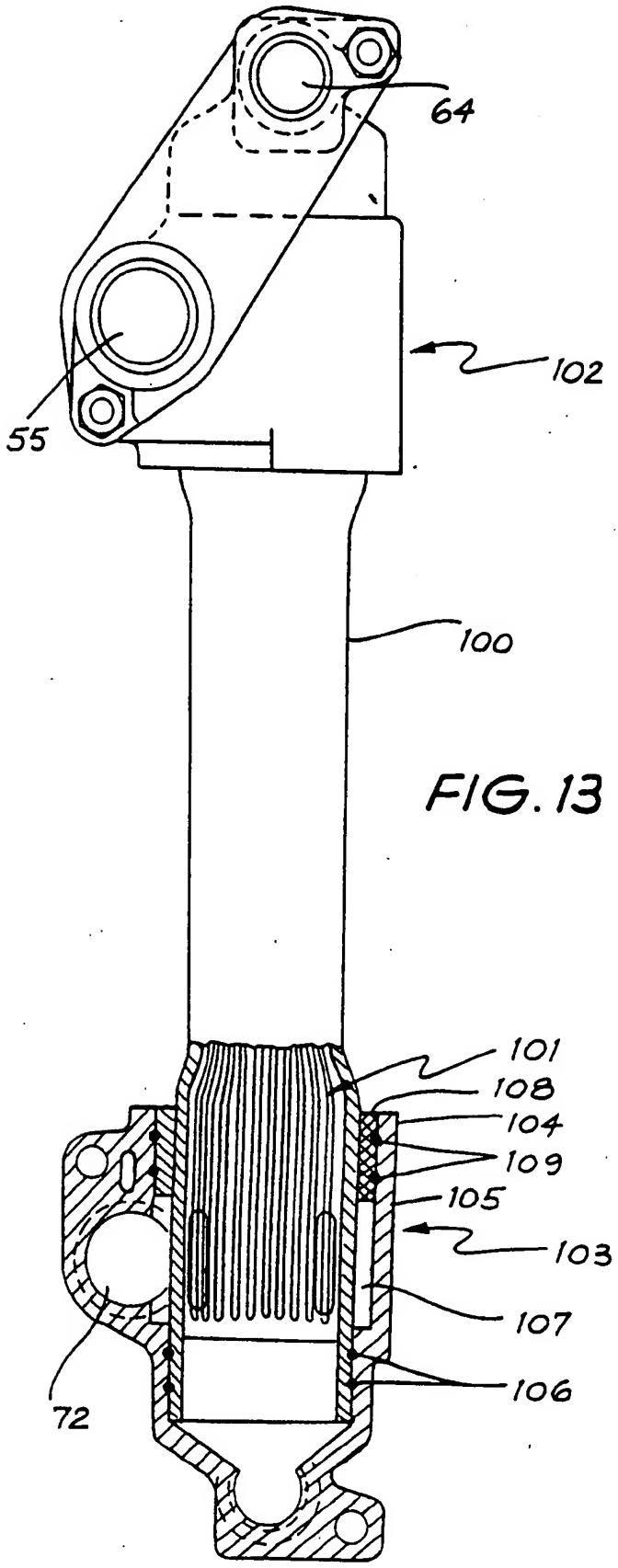


FIG. 13

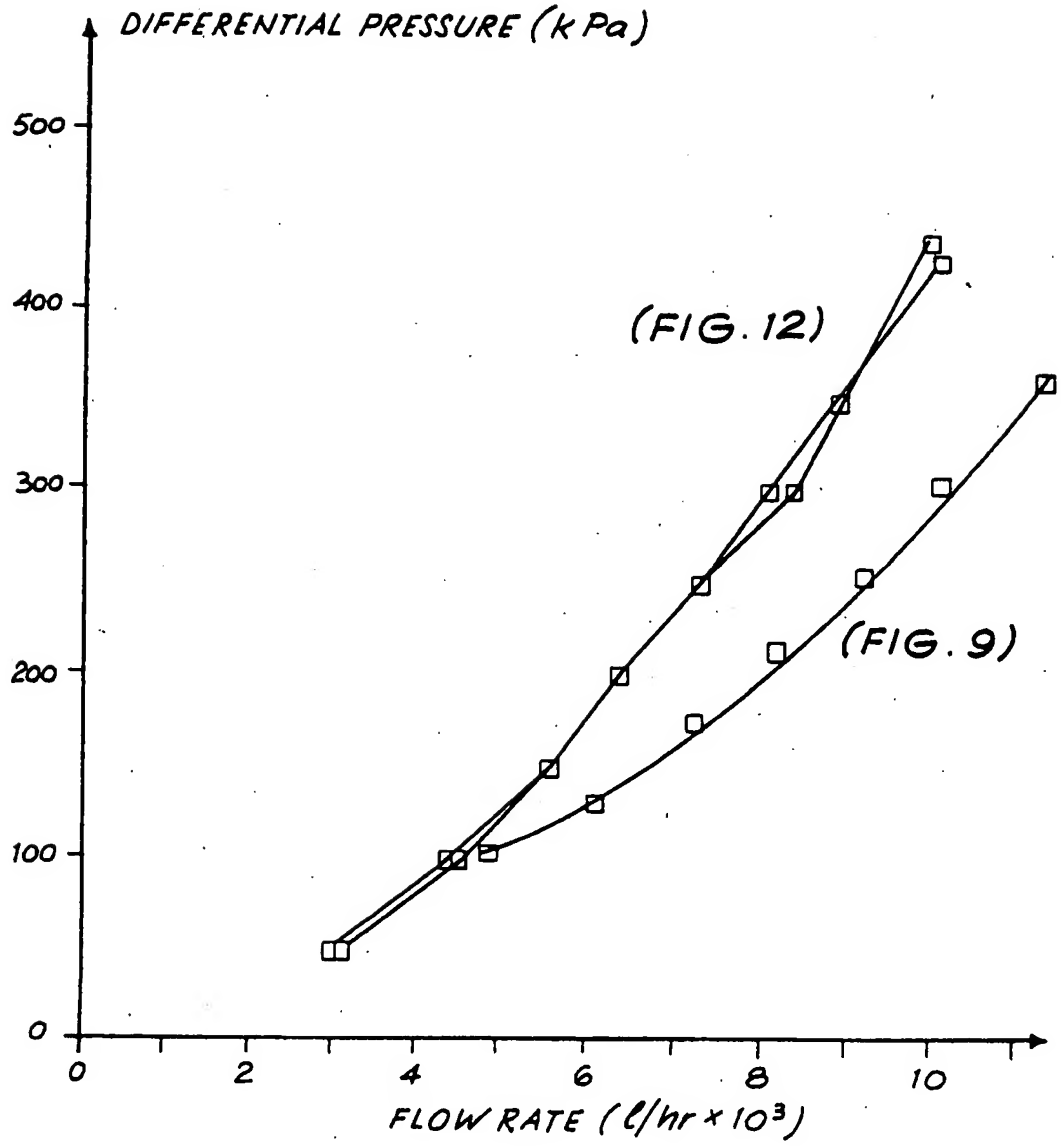

DIFFERENTIAL PRESSURE (k Pa)
500
400
300
200
100
0
0
2
4
6
8
10
FLOW RATE (ℓ/hr x 10³)
(FIG. 12)
(FIG. 9)

FIG. 14

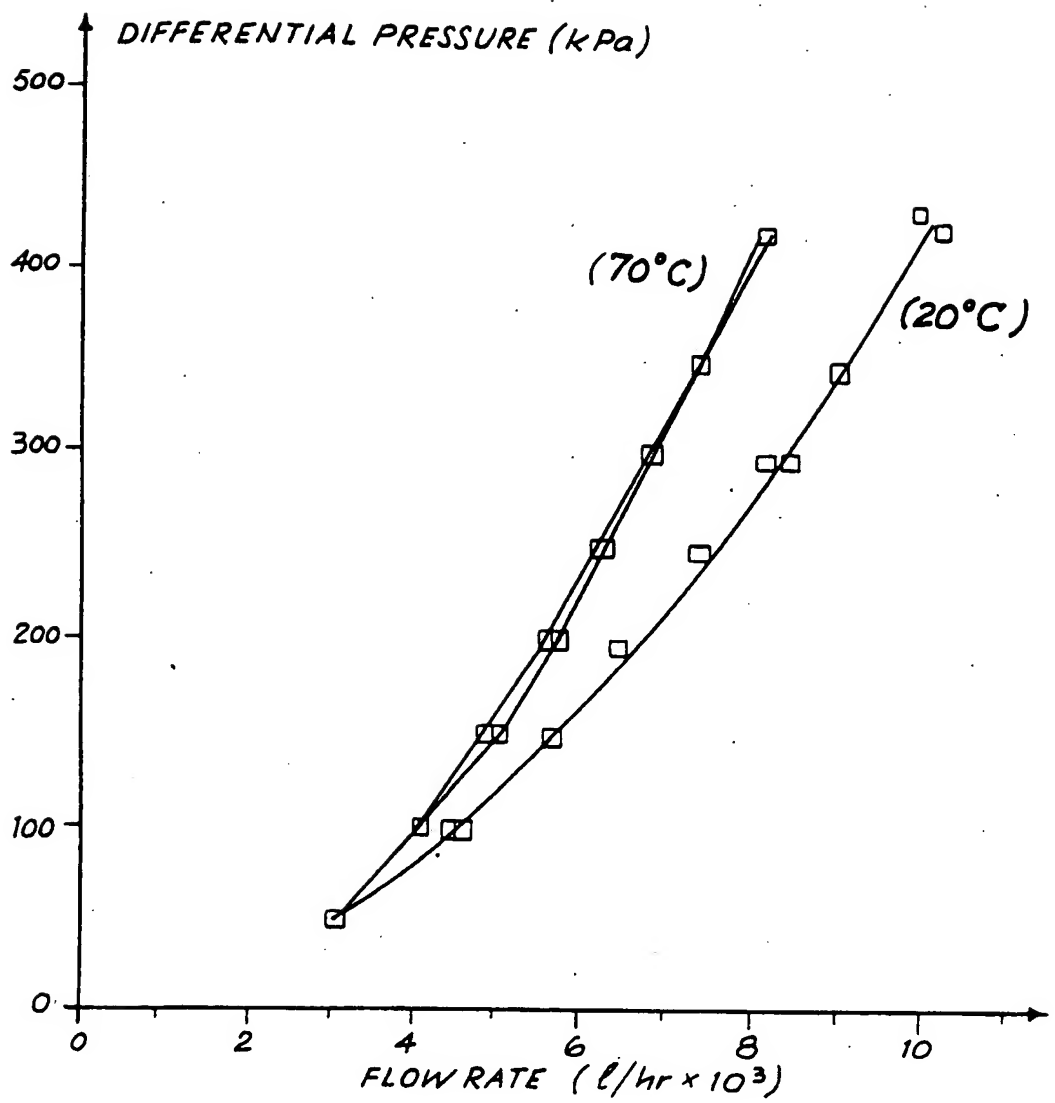
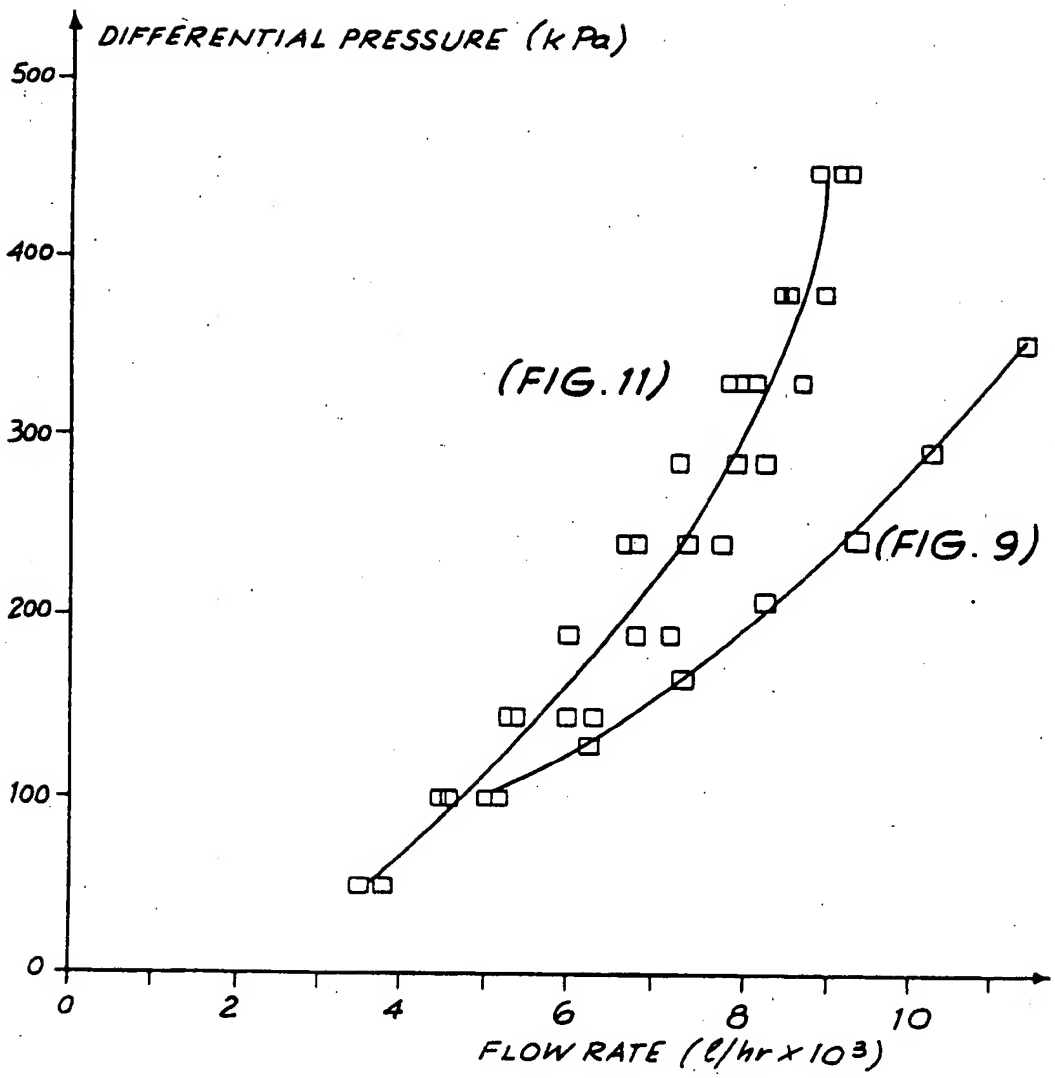

DIFFERENTIAL PRESSURE (kPa)
500
400
300
200
100
0
(70°C)
(20°C)
0
2
4
6
8
10
FLOW RATE (ℓ/hr x 10³)

FIG. 15


DIFFERENTIAL PRESSURE (kPa)
500
400
300
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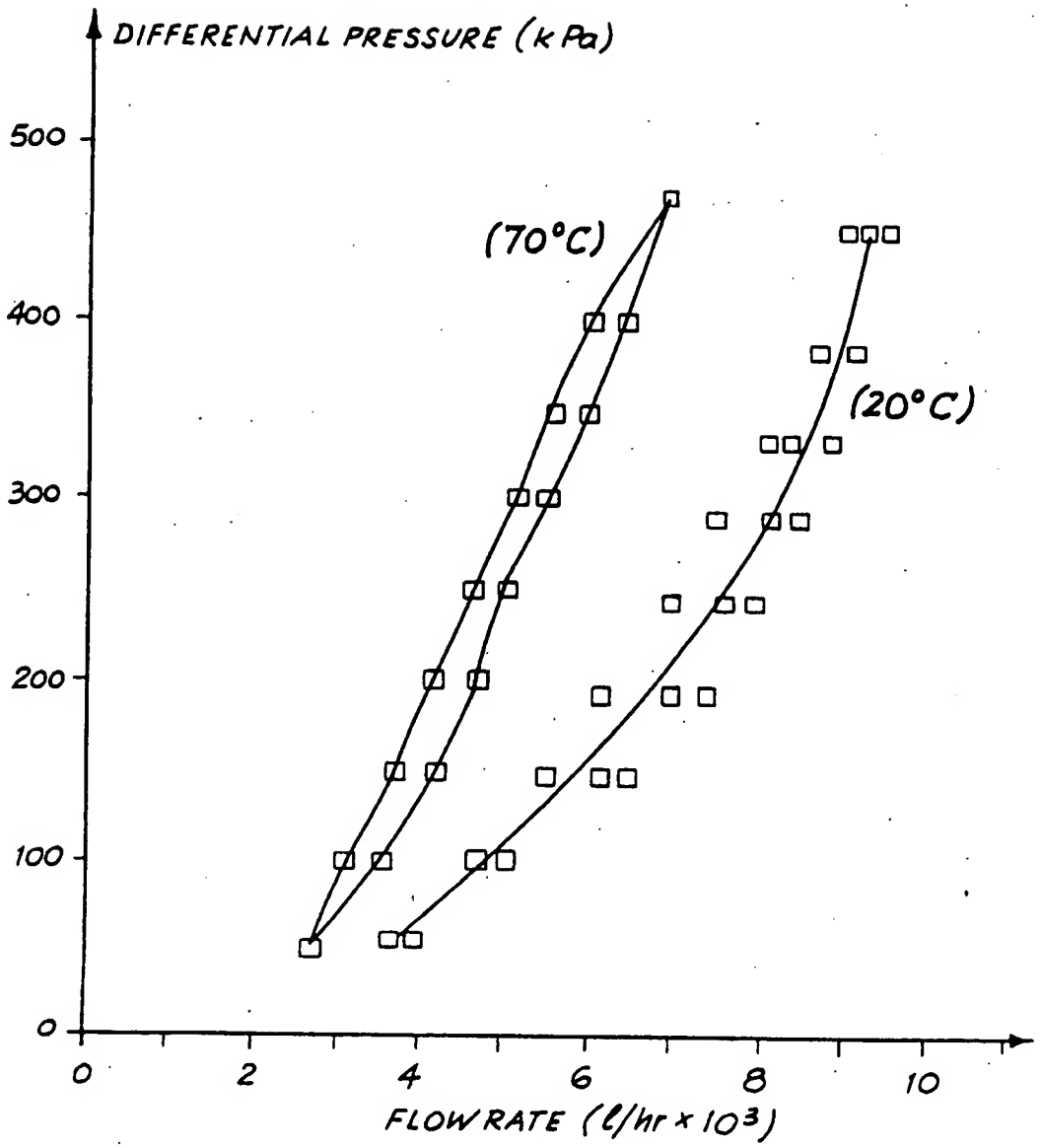
0
2
4
6
8
10
FLOW RATE (ℓ/hr x 10³)
(FIG. 11)
(FIG. 9)

FIG. 16


DIFFERENTIAL PRESSURE (kPa)
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400
300
200
100
0
(70°C)
(20°C)
0
2
4
6
8
10
FLOW RATE (ℓ/hr x 10³)

FIG. 17

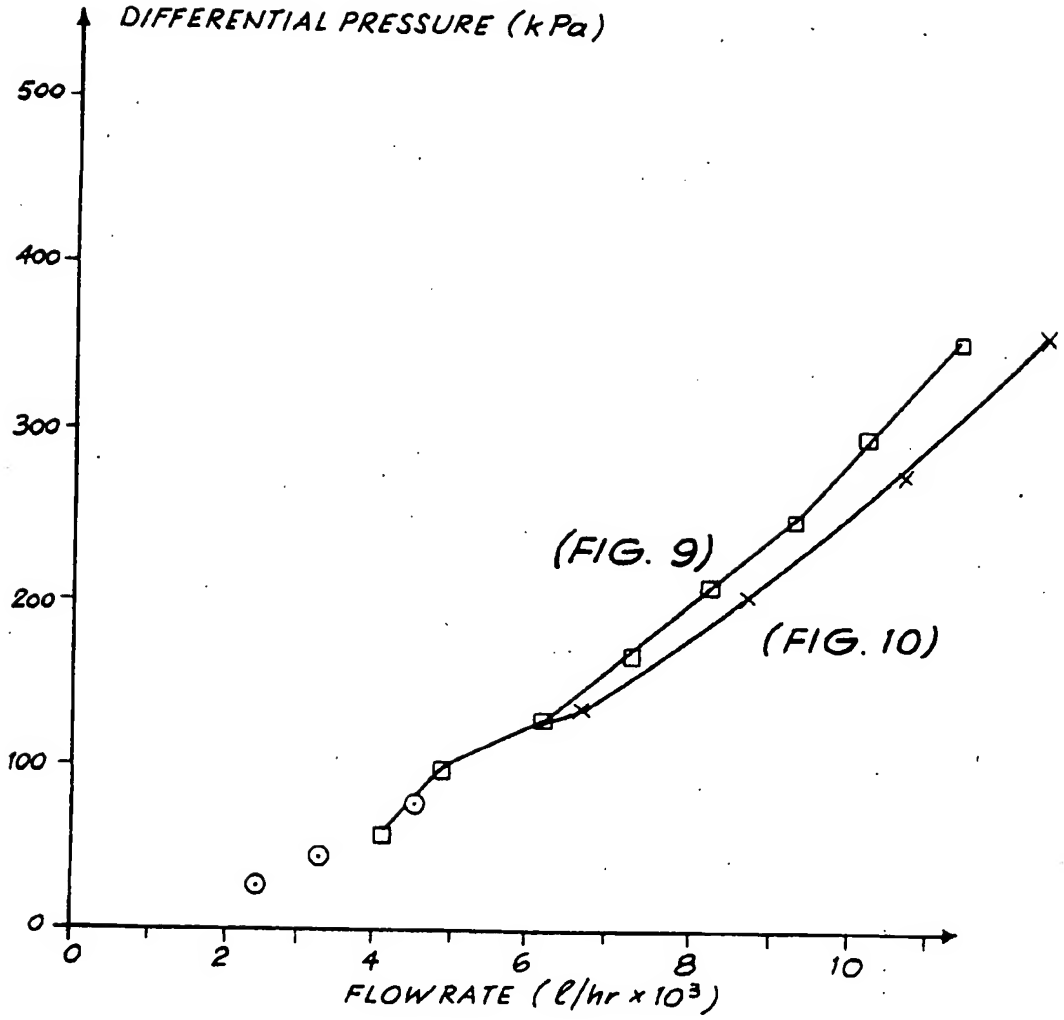
DIFFERENTIAL PRESSURE (kPa)
500
400
300
200
100
0
0
2
4
6
8
10
FLOW RATE (ℓ/hr x 10³)
(FIG. 9)
(FIG. 10)

FIG. 18